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MACROECONOMIC ANALYSIS AND SIMULATION

OF A STATE ECONOMY

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SUMMARY

The objective of this research was to analyze and simulate the state economic system in order to predict the behavior of many endogenous economic variables of interest under different input conditions and over a desired period of time.

In this thesis a macroeconomic model of a state economy was developed by considering four aggregate sectors of the total economy namely: population, government, business, and agriculture. Using the well-known concepts of macroeconomics, the basic model was formulated in terms of appropriate behavioral equations, technical equations and identities. The model was programmed in a special-purpose computer language, DYNAMO, which permits the analysis of the time paths of significant economic variables.

To validate the model, data relating to econometric study of the State of Michigan have been used. The simulation results showed close agreement between the actual data and the computed data.

CHAPTER I

INTRODUCTION

Nature of the Problem

Computer simulation is finding increasing use in the analysis and synthesis of many complex systems. The procedure of simulation is based on experimentation with a model representing as closely as possible an approximation of a complex real world system under study. An economic system is really a complex system wherein the analysis of various subsystems and their elements such as business cycles, money, transactions, product flows, price levels and the like, cannot be dealt with adequately using conventional analytical approaches and economic theorems. Simulation fills a large gap in economic analysis, especially when the system under study is a dynamic one with mutually interacting processes which involve non-linearities and time lags. The study of the behavior of the growth of a state economy essentially involves a macroeconomic analysis. Such analysis concentrates on aggregate magnitudes of the important variables of the total economy such as income, employment and price levels. It seeks to describe economic fluctuations and growth and suggests appropriate policy measures.

Although macroeconomic behavior of a national economy and of a state economy has a close resemblance in many respects, there are many differences in regard to certain variables and their economic analysis. A state economy may be regarded as a subsystem of a national economy. However, when considering a state as a system, it is imperative to realize that its economic growth is influenced by the economic policies and growth of other states and the nations. So, in a state pursuing the goal of economic development, the design of policy is made especially difficult, because of 1) the interdependence between the state and the nation, and 2) the degree to which policies aimed at one set of economic phenomena may have unintended side effects on other aspects of the economy. A further complication is that any state has a variety of goals, all of which must be considered in evaluating each policy action. Typically, a state government's policies are intended to contribute to the following list of objectives:

1) Increase Gross State Product or per capita product.
2) Reduce unemployment.
3) Establish a structure for continued development.
4) Maintain or hold down price level.
5) Maintain financial equilibrium between the state and the federal sources.
6) Provide adequate public service and facilities such as police service, education, health service, housing, sanitation and the like.
7) Provide adequate welfare facilities for unemployed, old and handicapped citizens. Such provisions are mainly subsidized from federal sources.

However, these economic goals are invariably affected by the following influences:

1) Investment policy

    a) Allocation of government investment.

    b) Degree of incentives and obstacles to private investment.

2) Fiscal policy

    a) Level and structure.

    b) Level and allocation of expenditures.

3) Credit and interest rate policy.

4) Federal aid and policy.

5) Population fluctuation as a result of increase in population and interstate migration.

Literature Survey

Classical economic theory was essentially limited to macroeconomics. The problem of efficient allocation of given resources such as labor, capital and materials within a closed economy was a subsidiary theme, not the main concern. The economic problem considered paramount by the classical economists such as Adam Smith (9) and Ricardo (17) was the long-run problem of the growth of the economy's productive capacity. Their analysis played down the demand aspect. These classical economists based their supply-oriented theory on the assumption that aggregate demand would always take care of itself. Other economists such as Malthus (4) and Marx (7) have advanced their theory under the influence of the post-industrial revolution era when socio-economic problems were more pronounced because of inequitable wealth distribution, poor employment conditions and rising population level.

In the neoclassical economics the main theme of the discussion is related to value and distribution--the area in which a major gap was left by classical economists. Neoclassical economists such as Pigou (19) have given more attention to the problem of efficient allocation of given resources. On this basis they have assumed that short-run problems of output and employment would be settled within the confines of the labor market. In other words, the supply of and demand for labor determines not only the real wage rate but also the level of employment. Therefore, any insufficient aggregate demand will be taken care of by wage and price flexibility and full employment will be assured. Thus, neoclassical writers did not develop a theory of aggregate demand as an explanation for income determination. This weakness of neoclassical theory was realized by Keynes (18). The neoclassical model was based on the following assumptions as outlined by Aschiem and Hsieh (21):

1) A closed private economy.
2) Given capital stock and technological and organizational knowledge in the short run.
3) A given quantity of money.
4) National output divided between consumption and investment expenditures.
5) Labor a homogenous factor.
6) Perfect competition in all markets.

Keynes (18), while rejecting the neoclassical theory of employment, advanced the new theory that at less than full employment, the equilibrium levels of output and employment were determined by aggregate demand. Keynes differences from the neoclassical theory can be summarized as follows:

1) Keynes assumed wages to be rigid for situations other than full employment instead of a function of supply-of-labor.

2) Keynes added the speculative demand of money as a function of interest rate to the neoclassical transactions and precautionary demand for money.

3) Keynes assumed that income would be a far more important determinant of saving (or consumption) than the neoclassical rate of interest.

Keynes theoretical economic system is summarized (22) in Figure 1.

One of the major trends in post-Keynesian macroeconomics is to formulate and extend Keynesian ideas in mathematical form. The post-Keynesian economists such as Musgrave (23) and others started with 'truncated' Keynesian models which may be represented by the following system of three equations in three unknowns:

$$Y_t = C_t + I_t$$

$$C_t = a + bY_t$$

$$I_t = I_o$$

where (Y) is output (real income); (C) is consumption expenditures; (I) is investment expenditures; (a) is the intercept of the consumption function, or the marginal propensity to consume. Another development in the post-Keynesian era was the use of 'multipliers' for finding the equilibrium values of endogenous

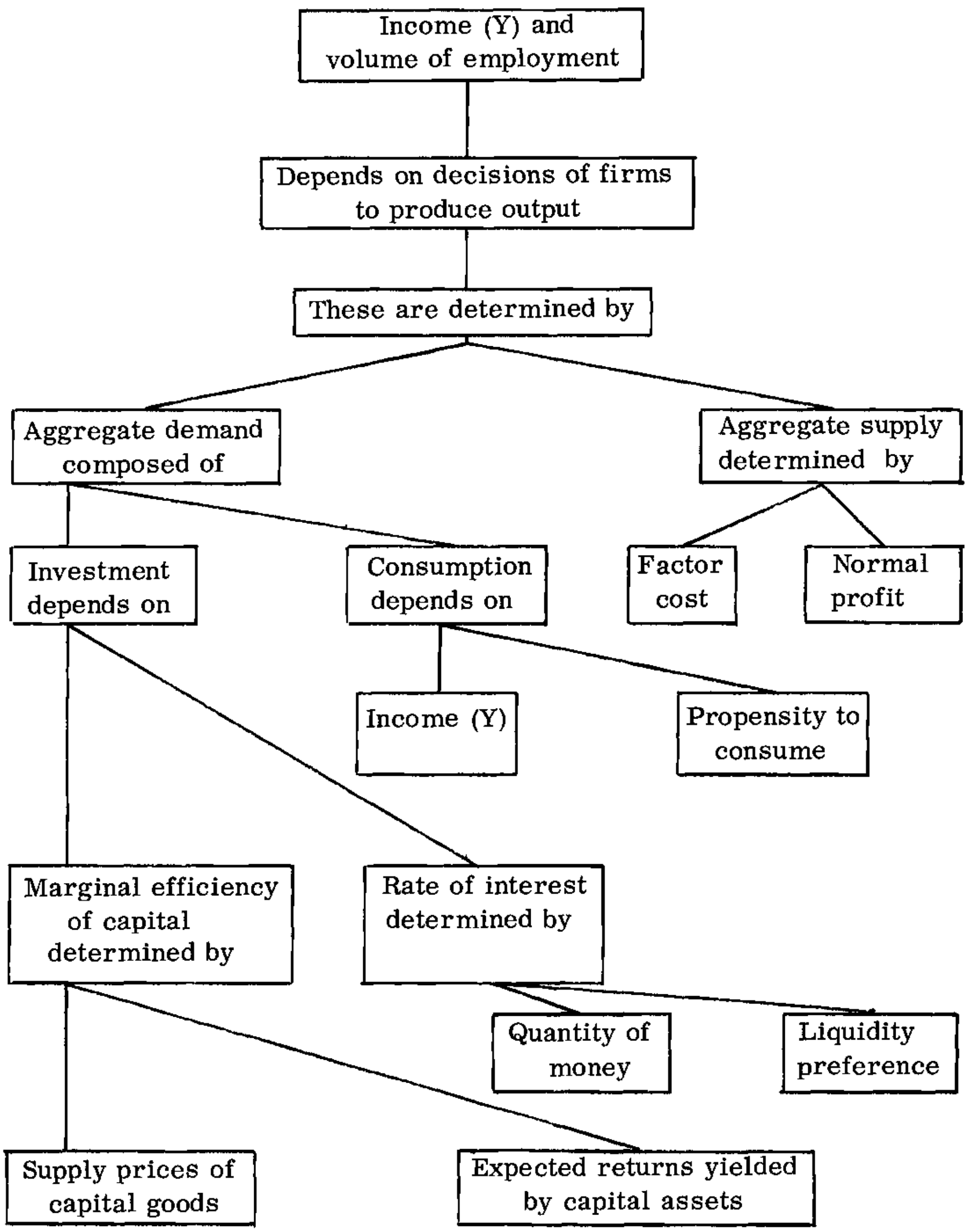


Figure 1. Keynes Economic System Model.

economic variables for given values of exogenous economic variables. The basic truncated model described above has been expanded to include more equations of different economic system variables. These models together with the use of multipliers formed the basis of static macroeconomics analysis of the present generation.

It is only in recent years that attempts have been made to develop dynamic models of economic systems based on the truncated models. Both deterministic and stochastic models were formulated to project the trends of economic behavior under different input conditions. These developments were possible due to improved economic statistics and the availability of computers. The efforts of such pioneering econometricians as Tinbergen (24) and Klein (25) appear to be causing significant progress in recent years. One of the most prominent efforts to describe a total economy at a macroeconomic level of aggregation is represented by The Brookings SSRC Quarterly Econometric Model of the United States (6). The model describes income determination in the short-run. However, it represents the process of economic growth since it contains the dynamic mechanism of capital accumulation and the mechanism of population and labor-force growth. The model contains more than 150 behavioral and technical equations and 15 identities.

Orcutt, Greenberger, Korbel, Rivlin (2) developed a stochastic micro-analytical model of a socio-economic system. It is a simulation of three basic components: 1) the decision makers such as individuals, families, firms, banks, labor unions, local governments and the like, 2) the markets and 3) the consumer goods and services. It was an experimental work and a limited demographic model of the United States was developed for the period 1950 to 1960. The results obtained from this simulation did not provide reliable predictions of economic behavior. However, writers believe that more intensive research is required on households, firms, governmental units, markets and other economic units to construct a more realistic microanalytical model.

With the development of DYNAMO compiler in recent years a new potential technique became available for analysis and simulation of diverse dynamic systems. Although this technique is still in an experimental stage, it has been applied to economic systems. As an example, an effort to simulate the total economy of India was made by Holland and Gillespie (14). The economy was divided into six sectors and the results obtained for the economic growth and balance of payments under several policy measures. This macroeconomic simulation has inspired the author to undertake the present study of a state economy. Another source of inspiration was the publication, Econometric Model of Michigan (16) concerned with the simulation of the economic behavior of the State of Michigan. The methodology developed in this study can be compared with approaches used in the above two publications.

Statement of Objective

The objective of this thesis is to develop a macroeconomic model of a state economy and the simulate it by means of a DYNAMO compiler. The State of Michigan was selected as a "model state" due to the availability of an econometric study of that state which provided data for comparison with the DYNAMO model.

It is expected that the results of this study will confirm the feasibility of using the DYNAMO compiler not only for the simulation of the economy of the State of Michigan but of any state, subject to the appropriate changes in the model specifications.

The Relevant System Elements and the Conceptual Model

Ideally, the behavior of each microcomponent of the system such as individual families, and banks should be considered and the aggregate effects analyzed. Such a model, although realistic, would be too complex, uncontrollable, and possibly too difficult to formulate. Besides, economic systems incorporate human behavior which unlike physical behavior involves many intangible attributes. In this study many important aggregate economic components were analyzed. First, the components or subsystems were identified and classified according to their similarity of economic behavior. Second, many relevant system elements were identified and included in the model. In this study the subsystems of the economy of the state are classified into four sectors as follows:

1) Population sector
2) Government sector
3) Business/Non-agriculture sector
4) Agriculture sector

These four sectors have several system elements operating within the system, according to certain behavioral laws of economics. There are other system elements such as public taxes, transfer payments, and the like which operate

A CONCEPTUAL MODEL

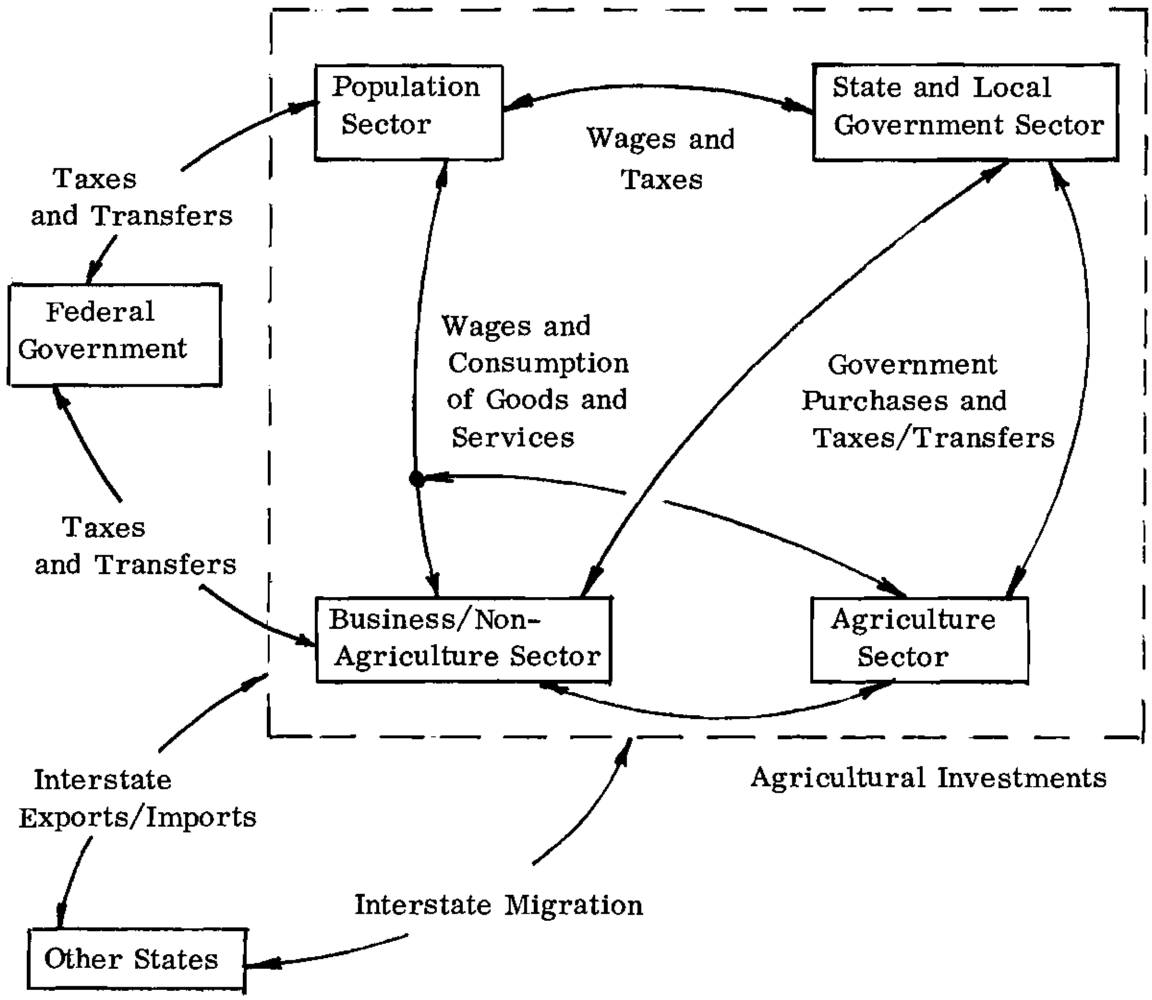


Figure 2. State Economy System Model.

to control the economic systems.

A conceptual model of the system is shown in Figure 2. The subsystems of the system under consideration are indicated within the boundary of the broken lines. It can be seen that there are external economic forces being exerted on the system such as interstate migration, export and import to and from other states and other economic forces. These economic forces have a definite effect on the economic level of activity of the state. Considering interstate migration, it is observed that depending upon the level of the engagement of labor force and unemployment, there will be migration tendencies between one state to another. Another important feature of this model is the effect of fiscal controls of federal government on the state economy. More detailed study of the aggregate effects of the subsystems will be followed in Chapter III.

CHAPTER II

PROCEDURE

The Plan of Attack

The present study is conceived as a series of steps. The entire procedure is described as follows:

(1) The specific problems related to the system were identified and the system boundaries were established.

(2) The system elements that were believed to be of importance within the system were isolated, and their importance was indicated.

(3) A conceptual model of the system was constructed.

(4) Flows and interactions of system elements corresponding to each sector or subsystem were represented on the basis of macroeconomic behavior.

(5) A mathematical model representing the flows and interactions of the system elements was constructed.

(6) The economic system formulated mathematically in step (5) was simulated through time using the DYNAMO compiler and numeral data pertaining to the economy of the State of Michigan.

(7) The model was reconstructed wherever descrepancies appeared to exist. The process was repeated until the entire model had validated.

(8) The model was analyzed to determine the influence of variables on the performance over time of such endogenous variables as gross state product and personal disposable income.

(9) The results of the simulation were related back to the real world system, and their importance discussed and analyzed.

The Simulation Language

The DYNAMO computer language was used in simulating the economic system. It is suggested for the reader who is unfamiliar with the DYNAMO language to refer to chapters six through nine of Jay W. Forrester's Industrial Dynamics (5) and sections 1.1 through 1.4 in Chapter One of Alexander Pugh's DYNAMO User's Manual (8).

There are several good reasons for the use of DYNAMO in the analysis and simulation of an economic system:

(1) The dynamics of an economic system can be stated in terms of either differential or difference equations. The structure of DYNAMO is designed for dealing with such dynamic systems. Incidently, the term DYNAMO is an abbreviation of DYNAmic MOdels.

(2) DYNAMO accommodates models involving complex nonlinear relationships which is common in an economic system.

(3) It provides for delays in action.

(4) The programming and debugging of the DYNAMO language is easy.

(5) The analysis and revision of the program can be made effectively without affecting the whole program.

(6) Its great computational speed provides efficient and economical computer usage.

(7) Its graphical output provides for easy sensitivity analysis of the model.

Data for the Model

Most of the necessary data for the model has been collected from the publication, Econometric Model of Michigan (16) and other governmental literature. Although, some of the data were assumed in the model, the output was tested for sensitivity analysis to see what effect assumed data had on the output.

Michigan factories, farms, mines and businesses contribute nearly five per cent of the value of all goods and services produced in the United States. For example, in the year 1964, the Michigan gross state product (GSP)--the total contribution of Michigan to the market value of all final goods and services produced in the United States--was $28 billion, compared to the corresponding gross national product (GNP) of $623 billion for the nation as a whole. In other words, nearly one dollar out of every twenty spent for the final products of American business was created by Michigan workers, managers, shareholders, and businessmen.

Of course, Michigan's share of the total market is not constant, but depends on the demand for Michigan products, relative to the total demand for goods and services produced in other states. In particular, the dominant Michigan industrial activity is the manufacture of motor vehicles and parts, together with the production of steel and other materials to be used in their manufacture. It follows that automobile demand is the most important influence on the state's economy.

CHAPTER III

MODEL FORMULATION

Preliminary Remarks

The importance of models as a means of studying complex real systems can hardly be overemphasized. In this chapter some general principles and concepts which should guide the formulation of an economic model will be discussed. A model of an economic system must have some reasonable relation to the different activities that compose the economy of a sector or a nation. However, it is not possible to represent all the activities in detail. Only activities that are believed to be most pertinent and significant are included and the rest omitted. Obviously, this approach requires knowledge of the economic system and the behavioral relationships within the activities. Further, several kinds of activities must be lumped together in each of the various aggregate quantities that represent the variables of the model. This grouping is done according to the purpose of the model and the similar characteristics of the economic variables. In the present scope of the study the following four aggregate sectors of economy are considered:

1) Population sector.

2) Government sector.

3) Business/Non-agriculture sector.

4) Agriculture sector.

Basis of Model Formulation and Assumptions Made

The model formulation essentially involves an application of macroeconomic theory. It requires the development of a set of macroeconomic equations which tie several pertinent economic variables, both exogenous and endogenous, under consideration. A macroeconomic equation can represent a behavioral equation, a technical equation, an identity or an equilibrium condition. The behavioral equations describe the behavior of various groups in the economy such as an aggregate consumption function, or a demand function. The technical equations describe technological relationships such as an aggregate production function, tax function or the relationship between input and output. An identity is an equation stating the equality that holds true by virtue of the definitions of the variables involved. For instance, an equation stating that the year-end capital stock of the current year is equal to the sum of the year-end capital stock of the preceding year and the net investment of the current year forms an identity. Finally, an equilibrium condition holds true because of the particular assumption postulated such as an equation stating that the demand for labor or a commodity is equal to the supply of the corresponding variable as supposedly existing under economic equilibrium condition. These four types of equations can be found in the model formulation.

The first sector describes the change in population given a certain birth rate and death rate over a period of time. A correction in the population change is incorporated as a result of in-migration and out-migration. The main cause of migration is attributed to the level of unemployment or the potential job opportunities in other states. However, there may be other intangible factors though seemingly insignificant that might be influencing the migration. The labor force was computed on the basis of the portion of the population that is 14 years and older. The labor participation rate is assumed to be constant as approximately 54 percent of total labor force, although there is a slight tendency of decrease over the years because of increasing prosperity of the population. The personal income was computed on the basis of average wage rate for a given year. The average wage is assumed to increase every year but no less than a certain percentage of increase of gross state product. The personal consumption is a function of average propensity to consume which was observed during the last decade to be around 90-92 per cent of the personal disposable income.

The government sector has multiple functions in the economy. The government collects taxes from or makes transfer payments to the rest of the sectors. The income earned by government through taxes constitutes the budget which may be surplus or deficit depending whether the proposed expenditures are less or more than the income generated through taxes plus net savings. In this study, only the effect of state and local government budgets was considered as influencing the state economy. The government expenses are classified into three broad categories viz., government investment in public utilities, government welfare, and government wage payments. However, the government interest payments and public debt are included in the model as a part of expenses. The extent of government expenditure and taxes was incorporated into the model to influence the demand for goods and services in accordance with the personal and business consumption. Thus, fiscal controls as applied through taxes and expenditures were assumed as the policy to stabilize the economic system. For instance, increasing the tax rate tends to reduce the personal and business consumption investment which further reduces the total demand for goods and services and vice-versa. Other economic side effects are the inflationary or deflationary tendencies in the economy as result of change in demand for goods and services on the one hand, and employment level on the other. The business sector consists of corporate enterprises and all unincorporated business enterprises such as family businesses, independent professional practitioners. All these enterprises produce goods and service which are sold at a price intended to cover at least the cost of production. Agriculture producing sector is, however, excluded from this sector. The demand for goods and services by businesses and population sector stimulates the supply of the same from the business sector. The demand for business sector appears mainly as the investment necessary to replenish the depreciated capital stock and to increase the productive capacity for more goods and services. In the economic equilibrium sense, the business investment equals net business saving. However, in practice business investment tends to differ more often than not with the net savings accrued in business operations. This difference causes unreal perception of the actual demand for goods and services. But such variations are practically taken care of in our economic system model through 1) governmental fiscal controls and 2) the interstate imports and exports of goods and services.

The main components of investment in the business sector are capital and labor. Their relative ratios are dependent on the types of industry or business operation. Various economic growth models have been proposed using capital and labor as inputs. According to the neoclassical economic concept, it is believed that in the very long run production may be considered to follow the law of variable proportion, that is, the capital and labor inputs are substitutable and the ratio in which the two inputs are used may change. One of the main contentions of the neoclassical model of economic growth is that under its assumptions of factor substitutability and factor price flexibility, a purely capitalistic economy can choose from a range of values for the capital-output ratio and the warranted rate of growth.

The following four assumptions about supply are made considering the three markets of output, capital investment and labor:

1. Firms supply output to the output market with perfect elasticity at a constant price level.
2. The money market is not considered.
3. The existing labor force is offered inelastically.
4. The existing capital stock is offered to the capital goods market inelastically.

Cobb and Douglas developed a production function through statistical investigation of the two main input variables, capital and labor. This function, called the Cobb-Douglas function, has the following form for the U. S. economy:

$$B(t) = K(t)^{a} . L(t)^{1-a} \text{ in which } 0 < a < 1$$

where B(t) is output

$K(t)$ is input of capital

$L(t)$ is input of labor -- all per unit of time at point t of time; and the exponent (a) denotes the elasticity of output with respect to capital input.

This production function has been used by various writers with some refinements in order to incorporate technical progress and improvements in the quality of capital and labor. As an example of a refined model, the production function may be written as

$$B(t) = A(t) . K(t)^{a} . L(t)^{1-a}$$

where $A(t)$ is factor representing technical progress and capital-labor quality improvement.

In the present economic model the value of the exponent (a) being unknown is determined using statistical time series in which the output, capital and labor quantities are on record. $A(t)$ is similarly determined, although it was found to remain stable and constant over the period of time under study.

The agriculture sector consists of production of food, livestock, and forest products. The agriculture production shows general trends of constant production with random fluctuations due to unforeseen weather circumstances. The labor force engaged in agriculture tends to decrease due to increasing migration of agricultural population to urban areas. This migration is caused by the decreasing demand for labor force required in agriculture as a result of improved technology on the farm. However, it was assumed in the model formulation that the decrease in farm labor force takes an exponential form while tending to stabilize asymptotically to a certain minimum value over the years. This assumption is based on the logical concept that regardless of the level of technology there would always be some labor force engaged on the farm. In terms of gross state product the contribution of the agricultural output is insignificant mainly because agricultural products do not substitute for other expensive consumer goods.

The following main assumptions were made in formulating the model:

1. Except for the interstate migration, the interstate imports relative to exports of goods and services are in balance.
2. The price of the output market is constant.
3. The quality of labor force is constant.
4. Government fiscal policy continues to be stable both in terms for public expenditure and as a controlling agent of consumer goods and services.
5. Money market is not considered; also, the interest rate affecting the money market is constant.
6. The average propensity to consume continues to remain constant.
7. The output from the business/non-agriculture sector follows the Cobb-Douglas production function using capital stock and labor as input.

Overall Model Flow Representation

The overall model flow diagram is represented in Figure 3. The flow

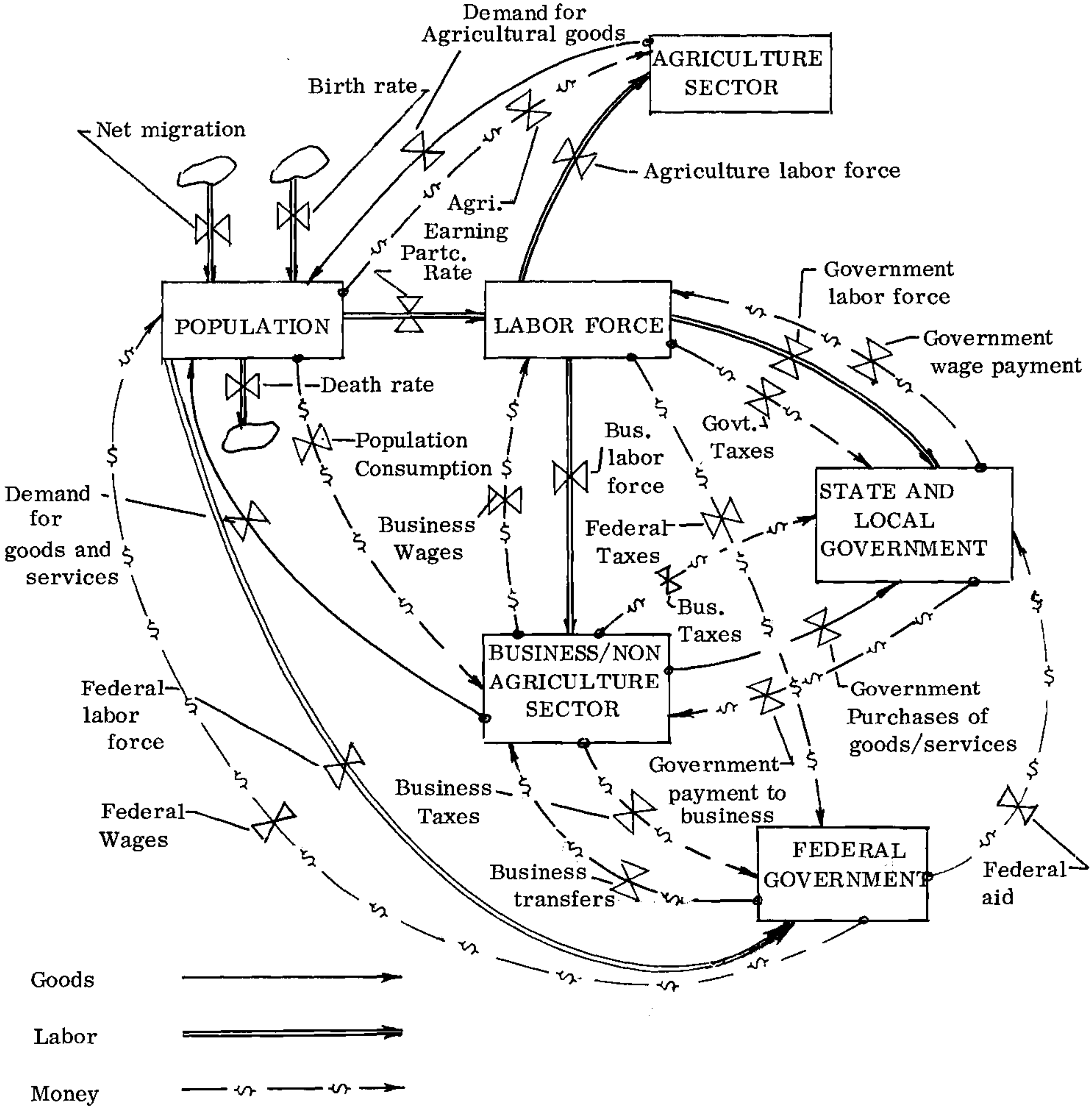


Figure 3. Money-Labor-Goods Flows Among Sectors.

diagram depicts the flows of labor, capital and goods. As may be seen, the population level at any time is controlled by birth rate, death rate and net migration. This population level provides two sets of employed labor. One set is engaged in business, agriculture and state/local government sectors, and the other set works for Federal Government. This latter set is a small proportion of the total labor force.

The money flows associated with labor wages, consumption of goods and services, and tax payments (net of transfers) are represented between various sectors of the state and the federal government. It may be observed that part of the federal money received as taxes is given to the state in the form of 1) federal welfare and social security, and 2) federal aid. Such federal receipts by the state and its people have bearings on both economic and non-economic factors. It is rather hard to isolate quantitatively these two factors and project their possible effects on the growth of the state economy because of variable federal fiscal policy. However, it was assumed that the federal receipts in any form by a state and its people are uniform and have marginal effect on the state economy. It was also assumed that intergovernmental transactions are in balance and have no effect on the state economy.

The goods and services produced by business sector have two main flows: 1) within the state and 2) exports to other states. Both of these flows incorporate investments by all business sectors, consumption by population, and purchases by the federal and local government. An assumption was made that while most of the demand for the goods and services by government and population is met locally, any import over export would have marginal effect on the state economy. Further, the economic effects of imports and exports were taken care of because the main output is independently measured through basic input variables such as labor and capital using the Cobb-Douglas production function rather than other components of the economy.

There are other less important economic variables such as personal and business savings, public debts, and interest payments which were not shown for the sake of clarity in the overall flow diagram but were incorporated in the sector flow diagrams discussed in Chapter IV.

CHAPTER IV

THE DYNAMO MODEL

General Remarks

This chapter is concerned with the construction of mathematical model based on the concept of the economic system described in earlier chapters. The model is formulated in DYNAMO language, reference to which has already been made in Chapter II. Simulation runs were carried out covering a time period of 40 years from 1952 (considered time T = 0) to 1992.

Population Sector

Figure 4 and Figure 5 combined represent the general structure of the population sector. The model formulation for this sector is developed in two submodels namely: population and labor force submodel, represented by Figure 4 and household submodel represented by Figure 5.

Population Sector: Population and Labor Force Submodel

In this section, equations describing the size of the population and the labor force will be developed. Figure 4 represents the flow diagram of this part of the population sector.

The initial value of the population level in 1952 was taken as 6,571,000. For the period T = 0 to 10 years, actual net migration rates NMR were used. For the period after T = 10 years, projected net migration rates NMR were used.

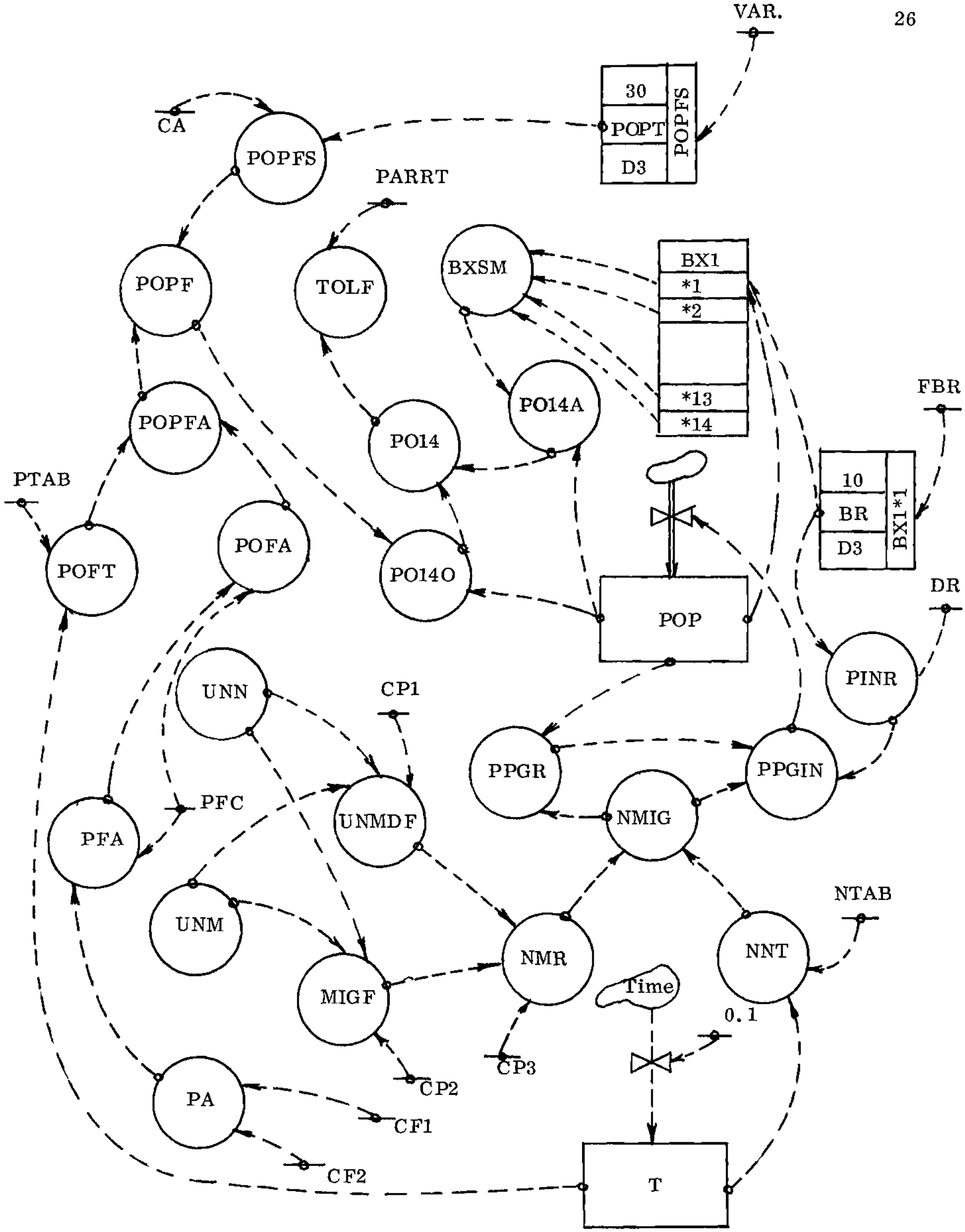


Figure 4. A Flow Diagram of Population and Labor Force Submodel.

These two distinct sources of migration data are operated upon by the CLIP function identified as NMIG.

In terms of DYNAMO language, the total population POP is expressed as a level equation incorporating the population increment rate PPGIN as a rate equation. This increment rate PPGIN consists of the sum of the net migration and population growth due to new births, defined as the product of population growth rate PINR and net population at any time PPGR. The values of projected net migration rates NMR are based on an empirical model which was originally used in the publication, Econometric Model of Michigan (16). The determination of NMR involves several auxiliary variables such as unemployment differential UNMDF, state unemployment level UNM and national unemployment level UNN. In addition, there are three constants CP1, CP2 and CP3.

The DYNAMO submodel of the total population level POP consists of the following 19 equations:

```
1L     POP.K=POP.J+(DT)(PPGIN.JK+0)
N      POP=6571E3
7A     PPGR.K=POP.K+NMIG.JK
14R    PPGIN.KL=NMIG.JK+(PINR)(PPGR.K)
N      PPGIN=136E3
C      PINR=BR-DR
C      DR=0.007
59A    NNT.K=TABLE(NTAB.K,T.K,0,10,1)
51R    NMIG.KL=CLIP(NMR.K,NNT.K,T.K,11)
1L     T.K=T.J+(DT)(1+0)
N      T=0
C      NTAB*=18E3/93E3/84E3/84E3/42E3/-27E3/-105E3/-94E3/-34E3/
       -82E3/-64E3
18A    UNMDF.K=(CP1)(UNM.K-UNN.K)
8A     NMR.K=UNMDF.K+MIGF.K+CP3
18A    MIGF.K=(CP2)(UNM.K-UNN.K)
C      CP1=-11.18
```

C CP2=-5.54
C CP3=-16.29

T	-Time reckoned from the year 1952
POP	-Total population (thousands of people)
PPGIN	-Population increment rate (thousands of people per year)
NMIG	-Net migration rate into the state (thousands of people per year)
PINR	-Population growth rate (people per person)
PPGR	-Net population in a given year including in-migration in preceding year (thousands of people)
NNT	-Net migration rate during period T=0 to 10 years (thousands of people per year)
NMR	-Net migration rate after 10 years (thousands of people per year)
UNMDF	-Intermediate variable called unemployment differential (dimensionless)
UNM	-State unemployment level (per cent)
UNN	-National unemployment level (per cent)
DT	-Incremental time called 'DELTA TIME' which is one year

The portion of the total population that is 14 years old and older is important as it represents the potential labor force. It is, therefore, imperative that, an attempt for an objective assessment of this portion of the population should be made. This segment of the population which is identified in the submodel as an auxiliary variable PO14 was determined as follows:

1) Two values of the portion of population that is 14 years old and older, identified as auxiliary variables PO140 and PO14A were determined through independent considerations. The value of PO14 was taken as smaller of the values PO140 and PO14A.

2) The value of PO140 is determined as a product of total population POP and a fraction of total population that is likely to be 14 years and older POPF. The value of POPF was taken as larger of the two values of the fraction of the POP that is 14 years old and older and identified as auxiliary variables POPFS

and POPFA. The values of POPFS and POPFA were also determined through independent considerations.

The value of POPFS was initially set at 0.74 at time T=0. However, it was estimated that this value gradually decreases with time to about 0.64. This decrease is expressed by means of a DELAY function identified as POPT. The POPT is intended to represent reduction from the value 0.64 by means of a constant VAR taken as 0.1, and the time period of 30 years.

To determine the values of POPFA, actual data of fraction of population that is 14 years and older POFT were used for the period T=0 to 10 years. For the period after T=10 years, projected value of the fraction of population that is 14 years and older POFA were used. These two values of POPFA were operated upon by a CLIP function. The variable POFA is expressed as an exponential function which uses intermediate variables PFA and PA, and constants PFC, CF1 and CF2.

3) The values of PO14A were determined by subtracting from the POP the sum of the portion of the population in age group 0 to 13 years BXSM. A boxcar function BX1 with 14 trains to carry population of age 0 (which is same as new births) in the first train and 13 years in the fourteenth train is used. Each train of the boxcar function is shifted linearly at shifting intervals of one year. The DELAY function identified by variable BR provided constant or exponential pattern of birth rate for a given value of final birth rate FBR and a delay of 10 years. An allowance of 0.3 per cent for death rate of population in the age group 0 to 13 years was made to get correct value: (0.997) (BXSM) of this portion of

population which is used (as indicated earlier) to determine PO14A.

The DYNAMO submodel of this portion of the population is expressed in the following 25 equations:

```
12A    PO140.K=(POPF.K)(POP.K)
7A     POPFS.K=CA1-POPT.JK
C      CA1=0.74
39R    POPT.KL=DELAY3(VAR,30)
C      VAR=0.1
N      POPT=0
56A    POPF.K=MAX(POPFS.K,POPFA.K)
51A    POPFA.K=CLIP(POFA.K,POFT.K,T.K,11)
59A    POFT.K=TABLE(PTAB.K,T.K,0,10,1)
C      PTAB*=.726/.720/.705/.710/.703/.700/.693/.689/.684/.682/.689
7A     POFA.K=PFC+PFA.K
C      PFC=0.675
C      CF1=-0.265
C      CF2=10
28A    PFA.K=(PFC)EXP(PA.K)
18A    PA.K=(CF1)(T.K+CF2)
37B    BX1=BOXLIN(14,1)
12A    BX1*1.K=(BR)(POP.K)
N      BR=0.024
39R    BR.KL=DELAY3(FBR,10)
C      FBR=0.024
C      BX1*164E3/162E3/159E3/155E3/154E3/153Es/118E3/117E3/121E3/123E3/
       113E3/103E3/96E3/95E3
53A    BXSM.K=SUM1(14,BX1.K)
14A    PO14A.K=POP.K+(-0.997)(BXSM.K)
54A    PO14.K=MIN(PO140.K,PO14A.K)
```

PO14 - The portion of the population that is likely to be 14 years and older (thousands of people)

POPF - Fraction of population that is likely to be 14 years and older (dimensionless)

POPFS - Fraction of population that is 14 years and older (dimensionless)

POPT - Decrease in fraction of population that is 14 years and older (dimensionless)

POPFA - Fraction of population that is 14 years and older (dimensionless)

POFT - The actual data of the fraction of the population that is 14 years and older (dimensionless)

POFA - The projected value of the fraction of population that is 14 years and older

PFA -Intermediate variable used in determining POFA (dimensionless)
PA -Intermediate variable as a function of time for determining PFA (dimensionless)
BX1 -Boxcar function containing 14 trains representing population from age 0 to 13 years
FBR -Final birth rate at end of 40 years (people per person)
BXSM -Sum of the people from age 0 to 13 years (thousands of people)
PO140 -The portion of the total population that is 14 years old and older (based on the value of POPF)(thousands of people)
PO14A -The portion of the total population that is 14 years old and older (based on the value of BXSM)(thousands of people)

The total labor force TOLF is computed by taking a product of participation rate of the labor force PARRT and the size of the population that is 14 years and older PO14. The value of PARRT is taken as constant 0.54.

The DYNAMO submodel of total labor force is given by the following equations:

```
12A   TOLF.K=(PARRT)(PO14.K)
C     PARRT=0.54
```

TOLF -Total labor force (thousands of people)
PARRT -Participation rate of the labor force (dimensionless)

Population Sector: Household Submodel

The submodel formulated in the previous section with reference to population and the labor force is interconnected with the household submodel. Such procedure is quite logical as essentially the household submodel is concerned with the population consisting of labor and non-labor force which have direct effect on the state economy. In this submodel variables describing personal wages, personal disposable income, personal consumption and the like will be considered. Figure 5 represents the flow diagram of this part of the population

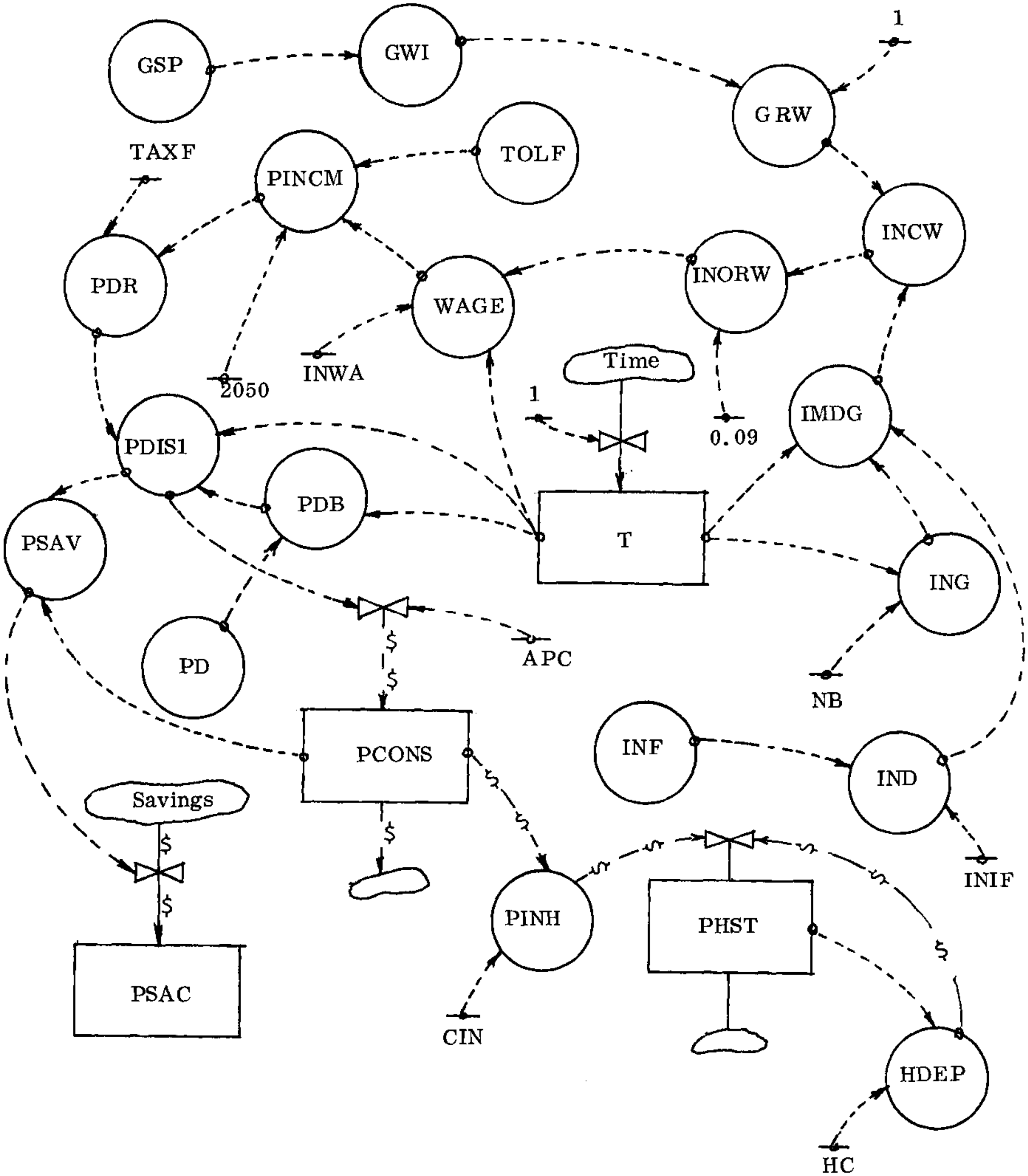


Figure 5. A Flow Diagram of Household Submodel.

sector.

The personal wages at any time are determined by an auxiliary variable WAGE expressed in terms of initial wage INWA and an annual increment in wages INCRW. The variable WAGE was assumed to vary linearly with time T. The increment INCRW is determined by maximum of two values, viz., INCW and \$0.09 per hour per year. In other words, minimum wage increment is at least \$0.09 per hour per year. The appropriate DYNAMO equations can be summarized as follows:

```
14A    WAGE.K=INWA+(INCRW.K)(T.K)
C      INWA=2.09
56R    INCRW.K=MAX(INCW.K, 0.09)
```

WAGE	-Wage rate (dollars per hour)
INWA	-Initial wage rate (dollars per hour)
INCRW	-Increment in wage rate (dollars per hour per year)
INCW	-Increment based on gross state product and inflation or deflation (dollars per hour per year)

The value of the auxiliary variable INCW is expressed in terms of two auxiliary variables viz., IMDG called implicit deflator of gross state product and GRW which is the maximum of unity and variable GW1. The value of GW1 is really half the percentage rate of growth of gross state product. In terms of DYNAMO language these relationships have the following form:

```
17A    INCW.K=(0.5)(IMDG.K)(GRW.K)+(-0.5)(IMDG.J)(GRW.K)
56A    GRW.K+MAX(GW1.K, 1)
22A    GW1.K=(1/GSP.J)((50)(GSP.K)+(-50)(GSP.J))
```

IMDG	-Implicit deflator in gross state product based on 1954 price level index as 100 (dimensionless)

GW1 -Half the percentage rate of growth of gross state product (dimensionless)
GSP -Gross state product (millions of dollars)

The variable IMDG has two sets of values operated upon by CLIP function. One set of values determined by variable ING uses actual data from time T=0 to 10 years; the second set of values determined by variable IND for time beyond 10 years is obtained by means of two intermediate variables INF and INIF. The DYNAMO equations of this submodel are summarized as follows:

```
51A   IMDG.K=CLIP(IND.K, ING.K, T.K, 11)
59A   ING.K=TABLE(INB.K, T.K, 0, 10, 1)
C     INB*=96.8/98.7/100.0/101.2/104.8/109.2/111.9/113.7/115.7/117.4/
      118.2
6N    INF=118.2
C     INIF=0.012
```

IMDG -Implicit deflator in gross state product based on 1954 price level index as 100 (dimensionless)
ING -The value of IMDG for the period T=0 to 10 years (dimensionless)
INF -The value of IMDG at time T=10 years (dimensionless)
IND -The value of IMDG after T=10 years (dimensionless)
INIF -The average increase in inflation per year (dimensionless)

The personal disposable income is the net income received by the labor force after all deductions such as income taxes, social security contributions and the like. According to the data available for ten year period (from T=0 to 10), the average deduction varied between 12 per cent to 14 per cent of the personal income earned. An average value of 13 per cent deduction based on actual data from T=0 to 10 years from personal income will be used for determining personal disposable income after 10 years. The two sets of values of personal disposable income are determined by means of a single auxiliary variable PDISI for period T=0 to 10 years is given by PDB in terms of a TABLE function and another set of values of PDISI for the period beyond 10 years is given by the auxiliary variable PDB which is expressed in terms of personal income PINCM and tax factor TAXF. The personal income is based on total wages earned for an average 2050 work hours per year. The tax factor is defined in this model as the fraction of personal income that forms the personal disposable income. The DYNAMO equations of the submodel has the following form:

```
51A   PDISI.K=CLIP(PDR.K, PDB.K, T.K, 11)
59A   PDB.K=TABLE(PD.K, T.K, 0, 10, 1)
C     PD*=11074E6/12540E6/12369E6/13873E6/14483E6/14781E6/
      14648E6/15383E6/15852E6/15873E6/16741E6
12A   PDR.K=(TAXF)(PINCM.K)
12A   PINCM.K=(TOLF.K)((2050)(WAGE.K))
C     TAXF=0.87
```

PDISI	-Personal disposable income (millions of dollars per year)
PDB	-The value of PDISI for the period T=0 to 10 years (millions of dollars per year)
PDR	-The value of PDISI for the period beyond 10 years (millions of dollars per year)
WAGE	-Average wage rate (dollars per hour)
PINCM	-Personal income (millions of dollars per year)
TAXF	-Tax factor which takes into account all the deductions from the personal income (dimensionless)

The personal consumption is given by an auxiliary variable PCONS and is expressed in terms of DYNAMO language as a level equation. Personal consumption PCONS depends on two main factors viz., personal disposable income PDISI and average propensity to consume APC. The value of APC was observed to remain a constant and is about 0.92. This submodel expressed in terms of DYNAMO language has the following form:

```
1L      PCONS.K=PCONS.J+(DT)((APC)(PDISI.K)-PCONS.))
N       PCONS=10180E6
C       APC=0.92
```

PCONS -Personal consumption (millions of dollars per year)
APC -Average propensity to consume

The personal savings represents the extra disposable income that is left after personal consumption and is expressed as an auxiliary variable PSAV. Assuming that all the personal saving is invested in savings account, the level of total savings at any time is expressed as PSAC in terms of DYNAMO language.

It is observed that on the average, approximately 15 per cent of the disposable income is invested or consumed in housing. Since housing can be treated like any other capital goods having certain span of life and rate of depreciation, a steady growth ot housing stock is observed. Personal housing stock at any time is given by PHST and is expressed in terms of DYNAMO language as a level equation incorporating PINH as personal investment in housing and HDEP as housing depreciation. The DYNAMO equations of the submodel is summarized as follows:

```
7A      PSAV.K=PDISI.K-PCONS.K
1L      PSAC.K=PSAC.J+(DT)(PSAV.K)
N       PSAC=911E6
12A     PINH.K=(CIN)(PCONS.K)
C       CIN=0.15
1L      PHST.K=PHST.J+(DT)(PINH.JK-HDEP.JK)
N       PHST=940E6
12R     HDEP.KL=(HC)(PHST.K)
C       HC=0.035
```

PSAV -Personal savings (millions of dollars per year)
PSAC -Personal savings account (millions of dollars)

PINH	-Personal investment in housing (millions of dollars per year)
CIN	-Fraction of disposable income invested in housing (dimensionless)
PHST	-Personal housing stock level (millions of dollars)
HDEP	-Rate of depreciation of housing (millions of dollars per year)
HC	-Fraction of housing stock being depreciated (dimensionless)

The Government Sector

In this sector only most important economic variables such as government expenses, government purchases, government labor force and the like will be used in the model formulation. Figure 6 represents the flow diagram of government sector.

Government employs labor force in order to help in carrying out many administrative and non-administrative activities in the various departments of the government. There exists a definite relationship between the size of government labor force and the size of population. However, in addition to the size of population, the volume of governmental activities and the employment policies do affect the size of the government labor force. The government labor force expressed in the model as GLAF is given by a level equation in terms of DYNAMO language. The annual increment of this labor force is given by the variable GLIN which has two sets of values operated upon by a CLIP function. One set of values is the actual data for the period T=0 to 10 and is expressed in terms of TABLE function by means of an auxiliary variable GT. Another set of values of GLIN is given by a variable GL which is assumed constant in the model for period over 10 years. The DYNAMO submodel is represented in the following equations:

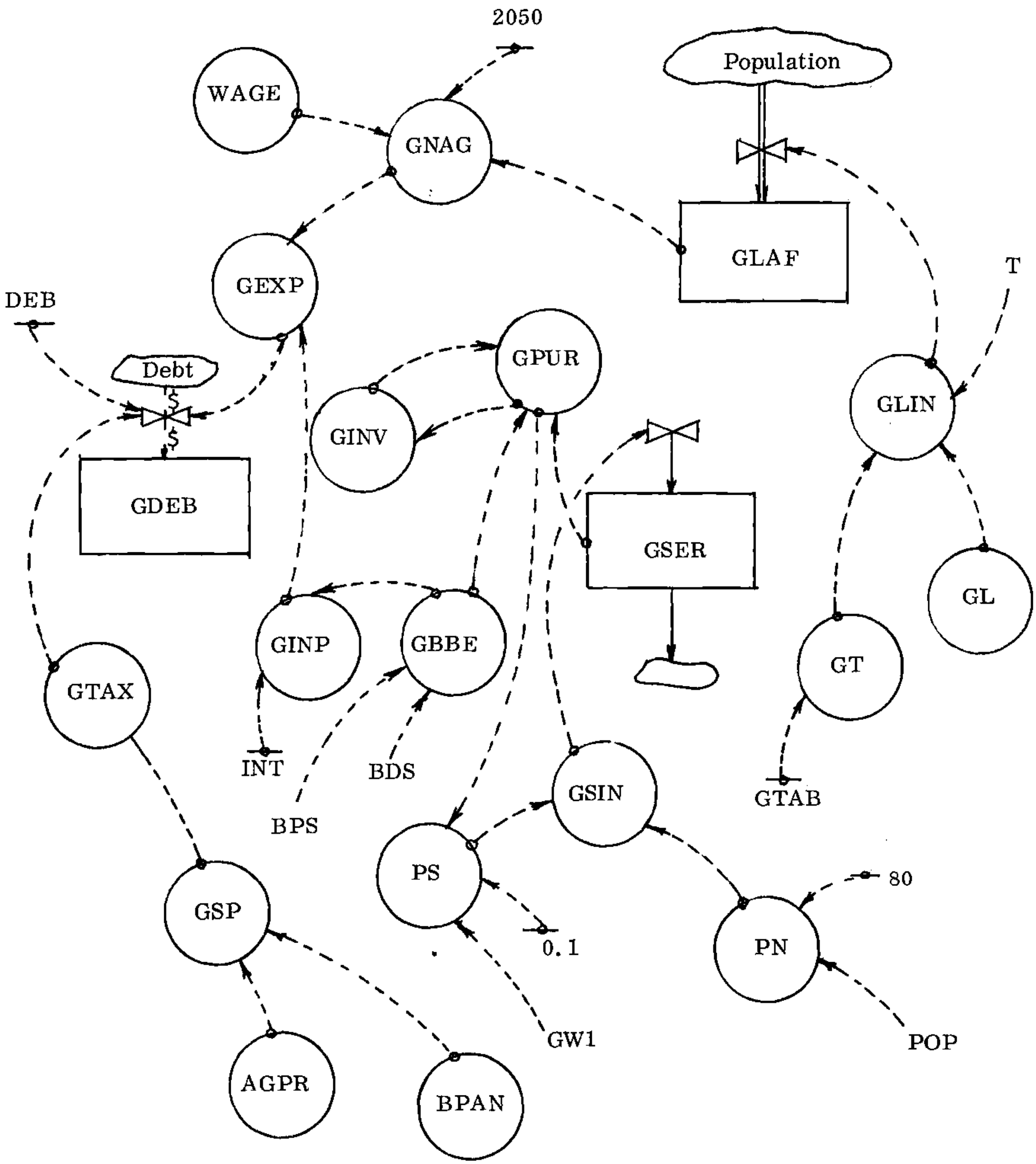


Figure 6. A Flow Diagram of Government Sector.

```
IL     GLAF.K=GLAF.J+(DT)(GLIN.JK+0)
N      GLIN=2E3
N      GLAF=108E3
51R    GLIN.KL=CLIP(GL,GT.K,T.K,11)
59A    GT.K=TABLE(GTAB.K,T.K,0,10,1)
C      GTAB*=0/7E3/2E3/5E3/293E3/2.5E3/4.8E3/4.4E3/8.0E3/4.2E3/4.3E3
C      GL=4E3
```

GLAF	-Government labor force (thousands of people)
GLIN	-Annual growth in government labor force (thousands of people per year)
GT	-Annual growth in government labor force for the period 0 to 10 years (thousands of people per year)
GL	-Expected average annual growth in government labor force after 10 years (thousands of people per year)

The total government payroll GWAG is a function of average wage rate WAGE per year and government labor force GLAF. It is assumed that average wage rate of the total labor force TOLF is the same as average wage rate of government employees assuming average work hours per year as 2050. In terms of DYNAMO language, the government wage equation has the following form:

```
12A    GWAG.K=(GLAF.K)((2050)(WAGE.K))
```

GWAG	-Annual government payroll (millions of dollars per year)
WAGE	-Average wage rate (dollars per hour)

Government purchases of goods and services GPUR can be broken down into three broad categories of purchases viz., in public investment GINV, public service GSER and government buffer expenses GBBE. The last category of government purchase is an optional one, designed to absorb or to encourage the flow of goods and services produced by business sector. This economic process is briefly as follows: in order that the growth of economy continues, sufficient demand for goods and services must be maintained; conversely, decline in demand for goods and services will tend to pull down the growth rate of the economy. Thus, government buffer expenses GBBE is used in this model as one of the fiscal controls which the government can exercise. The DYNAMO equations of the submodel have the following form:

```
8A      GPUR.KL=GINV.K+GSER.K+GBBE.K
N       GPUR=1187E6
```

GINV -Government investment (millions of dollars per year)
GSER -Government expenditure on public service (millions of dollars per year)
GBBE -Government buffer expenditure (millions of dollars per year)
GPUR -Government purchases of goods and services (millions of dollars per year)

Public service expenditures GSER is expressed in terms of DYNAMO language as a level equation. There has been a general trend during last decade or so for public service expenditure GSER to increase every year. This increase expressed in the model as the variable GSIN is contributed by two main causes viz., 1) the increase in gross state product and 2) the increase in population level. The value of GSIN depends on two intermediate variables i.e., PS and PN which have been related respectively to government purchases and per capita expenditure on public services. The submodel in terms of DYNAMO language has the following form:

```
1L      GSER.K=GSER.J+(DT)(GSIN.JK+0)
N       GSER=500E6
N       GSIN=300E6
54R     GSIN.KL=MIN(PS.K, PN.K)
12A     PS.K=(0.1)(GPUR.JK)
```

13A PN.K=(1+(GW1.K))(POP.K)(80)

GSER -Government expenditure on public service (millions of dollars)
GSIN -Increase in public service expenditure in any year over the preceding year (millions of dollars per year)
PS -Intermediate variable representing 10 per cent of government purchases in preceding year over the current year (millions of dollars per year)
PN -Intermediate variable representing per capita expenditure on public service (millions of dollars per year)
GW1 -Half the percentage rate of growth of gross state product (millions of dollars per year)

A certain fraction GKN of government purchases GPUR in any year is used in the next fiscal year on government investment GINV. This is due to a time lag of about a year in responding to the government purchases that are to be invested. Although, the value of GKN may change from year to year, it has been observed to remain constant during last decade. Government debts GDEB which constitute public debts mainly in the form of government bonds and loans from financial institutions are created as a result of extra government expenditure over the total receipts by the government. These debts are short-term as well as long-term and have to meet certain schedules of repayments. However, government has to pay interest GINP for the amount of debt GDEB it is holding. In terms of DYNAMO language, GDEB is expressed as a level equation which incorporates total government expenditure GEXP and government taxes GTAX. Government buffer expenditures GBBE which functionally serve as fiscal controls are assumed to depend mainly on desired business sales and possible business sales. Government taxes GTAX are assumed as fixed fraction 0.1 applied to gross state product GSP. The submodel expressed in terms of DYNAMO equation has the following form:

```
12A    GINV.K=(GKN)(GPUR.JK)
C      GKN=0.4
3L     GDEB.K=GDEB.J+(DT)(1/DEB)(GEXP.K-GTAX.K)
C      DEB=5
12A    GINP.K=(INT)(GDEB.K)
C      INT=0.03
N      GDEB=335.3E6
56A    GBBE.K=MAX((BDS.K-BPS.K),0)
12A    GTAX.K=(GSP.K)(0.1)
```

GINV	-Government investment (millions of dollars per year)
GKN	-Fraction of government purchases as government investment (dimensionless)
GDEB	-Government debts (millions of dollars)
DEB	-Delay in debts accumulation (years)
GINP	-Government interest payment (millions of dollars per year)
INT	-Interest rate (dimensionless)
GBBE	-Government buffer expenditure (millions of dollars per year)
BDS	-Business desired sales (millions of dollars per year)
BPS	-Possible sales expected in business sector (millions of dollars per year)
GTAX	-Government tax collections (millions of dollars per year)
GSP	-Gross state product (millions of dollars)

The total government expenditure GEXP during fiscal periof of one year is expressed as the sum of government payroll GWAG, government purchases GPUR, and government interest payment GINP. The DYNAMO equation of the government expenditure is expressed as follows:

```
8A     GEXP.KL=GWAG.K+GPUR.JK+GINP.K
```

GEXP	-Government expenditure during fiscal period of one year (millions of dollars per year)
GWAG	-Annual government payroll (millions of dollars per year)

GPUR -Government purchases of goods and services (millions of dollars per year)

GINP -Government interest payment on public debts (millions of dollars per year)

The Business/Non-agriculture Sector

The business/non-agriculture sector, henceforth called business sector, produces goods and services that are used by population, purchased by government and invested in the sector itself. Figure 7 represents the flow diagram of business sector. The model structure is intended to incorporate many significant variables such as business labor force, business production, business capital stock, business investment, and other factors which will be discussed in some detail in the paragraphs which follow.

Business labor force is identified by means of an auxiliary variable BLAF which is expressed in terms of two variables BFL and BLE through a CLIP function. The variable BLE uses the actual data of BLAF for period T=0 to 10 years. For period beyond 10 years, the business labor force BLAF is determined by the variable BFL. In terms of DYNAMO language BLE is expressed as level equation incorporating the rate of growth of labor force BLINC during T=0 to 10 year period. The values of BLINC are expressed in terms of TABLE function incorporating year to year increases in labor force. The value of business labor force beyond 10 years is given by an identity in which the value of BFL is equated to employed total labor force less government and agriculture labor force. The submodel expressed in terms of DYNAMO language has the following form:

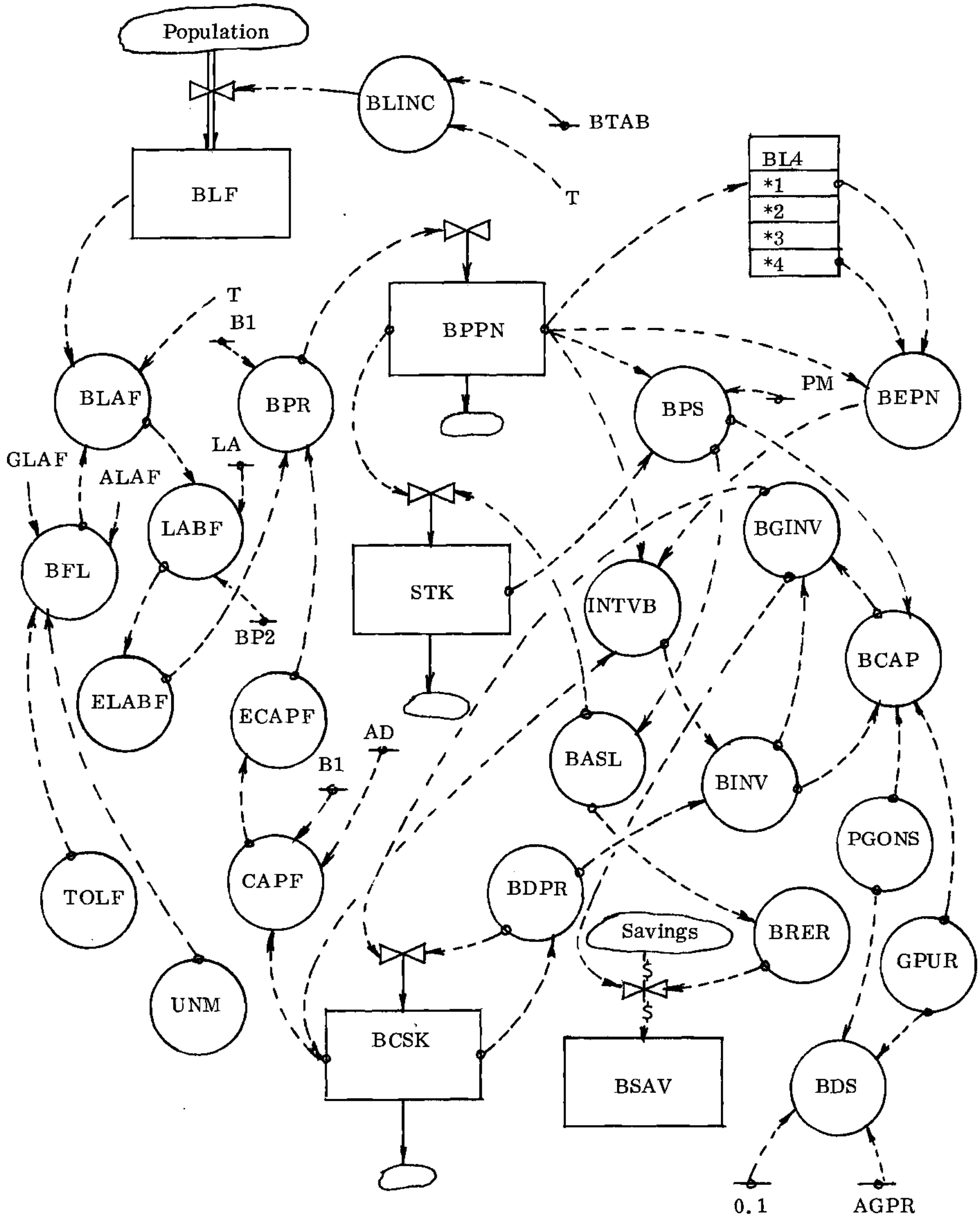


Figure 7. A Flow Diagram of Business/Non-agriculture Sector.

```
51A   BLAF.K=CLIP(BFL.K,BLE.K,T.K,11)
1L    BLE.K=BLE.J+(DT)(BLINC.JK+O)
N     BLE=2517E3
59R   BLINC.KL=TABLE(BTAB.K,T.K,0,10,1)
C     BTAB*=0/147E3/-13E3/-14E3/19E3/31E3/-58E3/-3E3/-7E3/0
16A   BFL.K=(TOLF.K)(1-(0.01)(UNM.K))+(-GLAF.K)(1)+(-ALAF.K)(1)
```

BLAF	-Business labor force (thousands of people)
BLE	-Actual values of business labor force during period T=0 to 10 years (thousands of people)
BLINC	-Actual values of increase of business labor force during period T=0 to 10 years (thousands of people per year)
BTAB	-Table values of increase of business labor force for T=0 to 10 year period (thousands of people)
BFL	-Business labor force after 10 years (thousands of people)
TOLF	-Total labor force (thousands of people)
UNM	-Unemployment rate of Michigan (per cent)
GLAF	-Government labor force (thousands of people)
ALAF	-Agriculture labor force (thousands of people)

The output from business sector is determined using Cobb-Douglas production function as discussed in Chapter III. The input variables to the model which determines output are business labor force BLAF and business capital stock BCSK. Expressed analytically, the output which is determined by variable BPR has the following form:

$$BPR = (BCSK)^{a}(BLAF)^{1-a} \text{ in which } 0 < a < 1$$

The value of exponent (a) which was found to give best fit for BPR is 0.7. In terms of DYNAMO language the submodel for business output has the following form:

```
12A   BPR.K=((ELABF.K)(B1))(ECAPF.K)
C     B1=1E6
29A   CAPF.K=(AP)LOGN((BCSK)(BP1))
29A   LABF.K=(LA)LOGN((BLAF.K)(BP2))
```

```
C       BP1=1E-6
C       BP2=1E-3
28A     ELABF.K=EXP(LABF.K)
28A     ECAPF.K=EXP(CAPF.K)
C       LA=0.3
C       AP=0.7
```

BPR -Business production (millions of dollars per year)
ELABF -Intermediate variable which is obtained from another intermediate variable LABF (dimensionless)
ECAPF -Intermediate variable which is obtained from another intermediate variable CAPF (dimensionless)
LABF -Labor factor which is obtained from the business labor force BLAF (dimensionless)
CAPF -Capital factor which is obtained from the business capital stock BCSK (dimensionless)

Possible business production BPPN at any time is given by a level equation incorporating BPR. It is assumed that about 2 per cent of inventory is carried over from certain point in time to the next point in time. The DYNAMO equation of possible business production is given by:

```
1L      BPPN.K=BPPN.J+(DT)(BPR.K-(0.980)(BPPN.J)
N       BPPN=15433E6
```

BPPN -Business possible production (millions of dollars per year)

The possible sales of goods and services of business sector BPS is a function of stock level STK, the possible business production BPPN, and utilization coefficient PM. The desired business sales is a function of government purchases GPUR, personal consumption PCONS, and a fraction of agriculture production. The last value is assumed to be the agriculture investment and purchases. Business stock STK is expressed in terms of DYNAMO language as a level equation incorporating business possible production BPPN and actual business sales BASL. Assuming 100 per cent effective sales effort, the actual business sales BASL should be the same as possible business sales BPS. The DYNAMO equations of the submodel have the following form:

```
14A   BPS.K=STK.K+(PM)(BPPN.K)
8A    BDS.K=GPUR.JK+PCONS.K+((AGPR)(0.1))
C     PM=0.95
1L    STK.K=STK.J+(DT)(BPPN.K-BASL.K)
6A    BASL.K=BPS.K
N     STK=(0.04)(BPPN)
```

BPS	-Business possible sales (millions of dollars per year)
BDS	-Business desired sales (millions of dollars per year)
PM	-Utilization coefficient of total of business possible production level (dimensionless)
STK	-Stock level of the output (millions of dollars per year)
BASL	-Business actual sales (millions dollars per year)

The business investment BINV is defined in the model as the sum of two variables viz., business depreciation rate BDPR and an intermediate variable INTVB which takes into account short-term expected growth rate in the output BEPN. A short-term forecast for BEPN is based on the average growth rate of business output during the previous four years. In terms of DYNAMO language the expression for BEPN is written as a boxcar function with four boxcars providing a linear shift once every year. The submodel for business investment has the following form:

```
11A   BEPN.K=BPPN.K+(BL4*1.K-BL4*4.K)/3
37B   BL4=BOXLIN(4,1)
6A    BL4*1.K=BPPN.K
C     BL4*=17959E6/15696E6/16923E6/15433E6
```

46A INTVB.K=(BCSK.K)(BEPN.K-BPPN.K)(1.5)/((BPPN.K)(1)(1))
7A BINV.K=BDPR.JK+INTVB.K

BEPN -Business expected production (millions of dollars per year)
BPPN -Business possible production (millions of dollars per year)
BL4 -Boxcar function with four boxcars assuming the values of BPPN.
INTVB -Intermediate variable dependent on business capital stock (BCSK), business expected production (BEPN) and total output (BPPN)
BDPR -Business depreciation rate (millions of dollars per year)
BCSK -Business capital stock (millions of dollars)

The capacity required in business operation is in some way related to the volume of sales. The increase in capacity must therefore be related to increase of possible sales over the consumption and investment. Business gross investment BGINV takes into consideration the capacity increment in addition to normal business investment BINV. Business capital stock BCSK is expressed in terms of DYNAMO language by a level equation incorporating business gross investment and business depreciation BDPR. It is assumed that certain percentage of business capital stock is linearly depreciated every year. This percentage is taken as 5.5 per cent, which is representative for depreciation of physical plant. Business retained earnings BRER is in some way dependent on business actual sales BASL. An average of 8 per cent applied to business actual sales BASL is assumed to represent business retained earnings BRER. The business savings BSAV at any time is actual savings plus excess of retained earning BRER over the gross investment BGINV. The DYNAMO equations of the submodel are summarized as follows:

9A BCAP.K=BPS.K-PCONS.K-GPUR.JK-BINV.K
11A BGINV.K=BINV.K+MAX(BCAP.K/2,0)

1L	BCSK. K=BCSK. J+(DT)(BGINV. JK-BDPR. JK)
N	BCSK=33523E6
12R	BDPR. KL=(0. 055)(BCSK. K)
11A	BRER. K=(0. 03)(BASL. K)
1L	BSAV. K=BSAV. J+(DT)(BRER. K-BGINV. K)
N	BSAV=500E6

BCAP	-Business capacity (millions of dollars per year)
BGINV	-Business gross investment (millions of dollars per year)
BCSK	-Business capital stock (millions of dollars)
BDPR	-Business depreciation rate (millions of dollars per year)
BRER	-Business retained earning (millions of dollars per year)
BSAV	-Business savings (millions of dollars per year)

The Agriculture Sector

In this sector two of the most important economic variables are agriculture labor force ALAF and agriculture production AGPR. Figure 8 represents the flow diagram of agriculture sector. The values of agriculture labor force and agriculture production do not show similar trends as is the case of business sector. There is general trend of continuous decrease of agriculture labor force due to improved technology on farm operation requiring less but more skilled manpower, and continuous migration of farm labor force to urban areas where higher paying jobs in industries are available. On the other hand, agriculture output tends to remain the same year after year except for random variation caused by unforeseen weather circumstances. In terms of DYNAMO language the variable ALAF is expressed as a level equation incorporating AGILF which represents an increase in agriculture labor force. Actual data of AGILF have been used for period T=0 to 10 years. Beyond 10 years an exponential decrease with initial value of four thousand per year is assumed. The submodel for agriculture labor force ALAF has the following form:

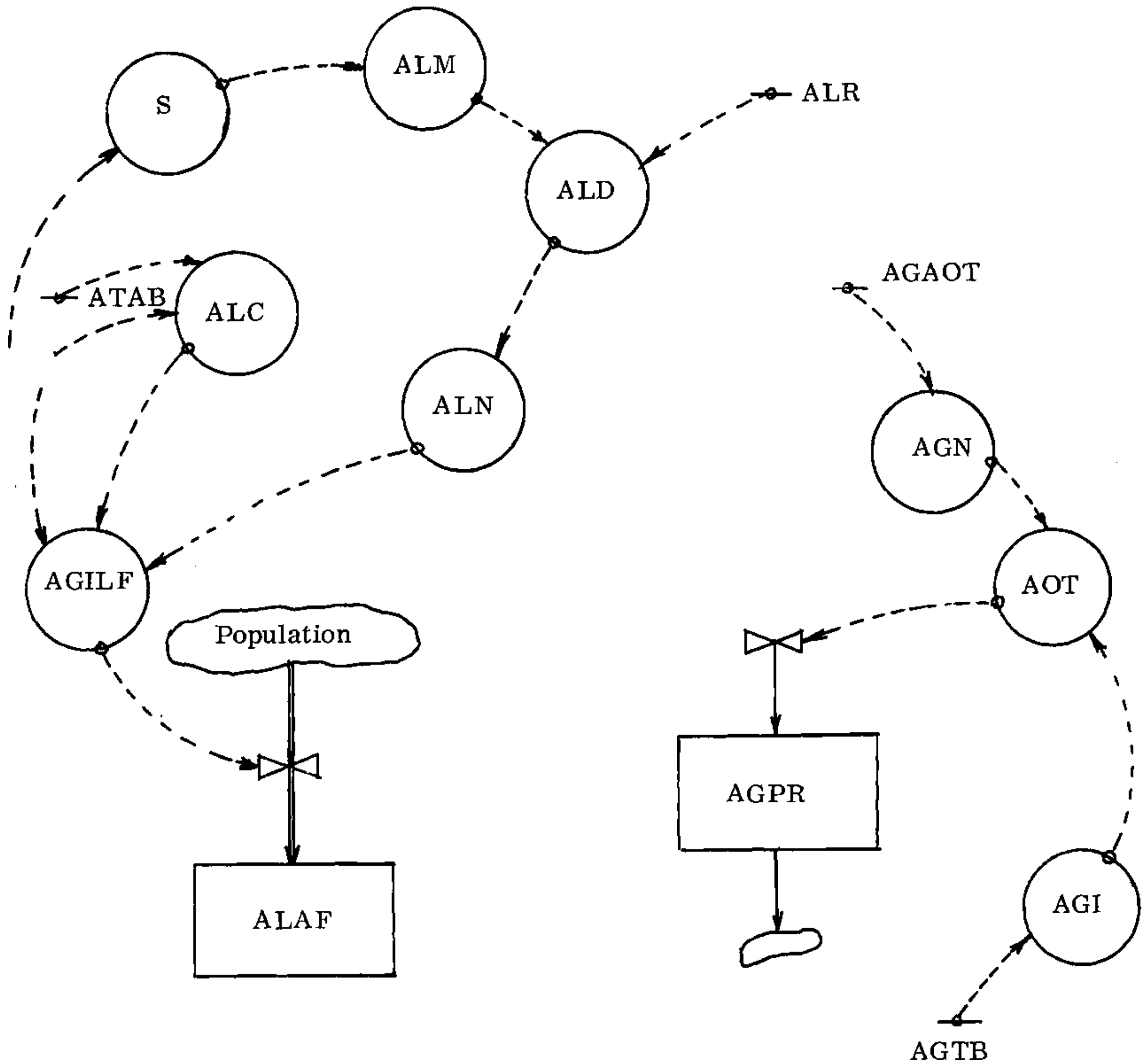


Figure 8. A Flow Diagram of Agriculture Sector.

```
1L     ALAF.K=ALAF.J+(DT)(AGILF.JK+0)
N      ALAF=141E3
51R    AGILF.KL=CLIP(ALN.K,ALC.K,T.K,11)
59A    ALC.K=TABLE(ATAB.K,T.K,0,10,1)
C      ATAB*=-4E3/-6E3/-2E3/-2E3/-6E3/-8E3/-7E3/-6E3/-7E3/-3E3/-4E3
6A     ALN.K=-ALD.JK
14R    ALD.KL=--AIR+(ALR)(ALM.K)
28A    ALM.K=EXP(S.K)
48A    S.K=1/(T.K+1)
C      ALR=40E3
```

ALAF	-Agriculture labor force (thousands of people)
AGILF	-Agriculture increase in labor force (thousands of people per year)
ALC	-Actual value of AGILF for period T=0 to 10 years (thousands of people per year)
ALN	-The value of AGILF for period beyond 10 years (thousands of people per year)
ALR	-A constant used as an intermediate value for determining ALD (dimensionless)
ALM	-Exponential value of an intermediate variable S (dimensionless)
S	-A dependent variable depending on time variable (dimensionless)

The agriculture production AGPR is expressed in terms of a level equation incorporating agriculture output AGOT and the excess of production carried over from previous year. Two sets of values for variable AGOT are used. One set takes actual data from T=0 to 10 years expressed by variable AGI by means of a TABLE function and another set takes the values given by the variable AGN for period beyond 10 years. The two sets of values are operated by a CLIP function. The value of AGN is based on random variation of an average agriculture output AGAOT set at 500 million dollars. The submodel for agriculture production AGPR can be summarized as follows:

```
1L     AGPR.K=AGPR.J+(DT)(AGOT.JK-(0.970)(AGPR.J))
N      AGPR=459E6
51R    AGOT.KL=CLIP(AGN.K,AGI.K,T.K,11)
```

59A	AGI.K=TABLE(AGTB.K, T.K, 0, 10, 1)
C	AGTB*=492E6/456E6/381E6/519E6/481E6/497E6/467E6/476E6/524E6/466E6/504E6
34R	AGN.K=(AGAOT)NORMRN(1, 0.005)
C	AGAOT=500E6

AGPR	-Agriculture production (millions of dollars)
AGOT	-Agriculture output (millions of dollars per year)
AGAOT	-Average agriculture output (millions of dollars per year)
AGI	-Actual value of AGOT for period T=0 to 10 years (millions of dollars)
AGN	-The value of AGOT for period beyond 10 years (millions of dollars per year)

There are some supplementary values and economic variables that are used in formulation of model and are as follows:

6A	UNM.K=6
6A	UNN.K=5
7A	GSP.K=BPPN.K+AGPR.K

UNM	-Average level of unemployment in the state of Michigan (per cent)
UNN	-Average level of national unemployment (per cent)
GSP	-Gross state product (millions of dollars per year)

Having developed a macroeconomic model of the state economy, some of the economic ratios may be considered as reasonable measures of its behavior. The following nine ratios are proposed:

20R	GGSP.KL=GEXP.JK/GSP.K
20R	BGSP.KL=BGINV.K/GSP.K
20R	PGSP.KL=PCONS.K/GSP.K
20R	PPOP.KL=PDISI.K/POP.K
20R	GPOP.KL=GEXP.K/POP.K
20R	HPOP.KL=PHST.K/POP.K
20R	BPOP.KL=BGINV.K/POP.K
20R	GNOP.KL=GSP.K/POP.K
20R	AGSP.KL=AGPR.K/POP.K

The notation used is as follows:

GGSP -Total government expenditure per gross state product (dimensionless)
BGSP -Gross business investment per gross state product (dimensionless)
PGSP -Personal consumption per gross state product (dimensionless)
PPOP -Per capita personal disposable income (dollars per year)
GPOP -Per capita total government expenditure (dollars per year)
HPOP -Per capita investment in housing (dollars per year)
BPOP -Per capita gross business investment (dollars per year)
GNPO -Per capita gross state product (dollars per year)
AGSP -Per capita agriculture production (dollars per year)

The complete program is shown in Appendix A. Simulation results are discussed in the next chapter.

CHAPTER V

SIMULATION RESULTS

General Description

In the previous chapter the mathematical model formulated in terms of DYNAMO language was used to simulate the macroeconomic system, over a 40 year period. The simulation results obtained in the form of computer print-outs and plots are discussed in this chapter.

Model Results

In this section some of the important variables are discussed and examined by means of their graphic plots. The complete print-out of the results is included in Appendix B in tabular form. Eight independent runs, as shown in Figures 9 through 16, were obtained taking different sets of parameter values as shown in Table 1. These runs show the economic variables of interest plotted on suitable scales. The notations T, M and B stand respectively for thousand (E+03), million (E+06) and billion (E+09).

Model Results: Figures 9 through 12

In these runs, the graphical plot of gross state product GSP, birth rate BR, population POP, personal income PINCM, personal disposable income PDISI and per capita agricultural production AGSP are shown. The other three variables shown are based on unit gross state product, such as a ratio of government

Table 1. Parameter Values Used in Figures 9 through 16.

Fig. No.	Parameters APC	PARRT	FBR
9	0.92	0.54	0.024
10	0.85	0.54	0.024
11	0.92	0.54	0.020
12	0.92	0.44	0.024
13	0.92	0.54	0.024
14	0.85	0.54	0.024
15	0.92	0.54	0.020
16	0.92	0.44	0.024

Notation: APC = Average propensity to consume
PARRT = Participation rate of the labor force
FBR = Final birth rate at the end of the run

expenditure GEXP/GSP=GGSP, a ratio of business investment BGINV/GSP=BGSP, and a ratio of personal consumption PCONS/GSP=PGSP. Using Figure 9 as a reference, the results are summarized in Table 2.

The following comments are in order concerning results shown in Table 2 and in Figures 9 through 12:

1) A decrease in average propensity to consume APC by 7 per cent results in 14 per cent increase in business investment per gross state product BGSP and

than either GSP or BGSP. The value of personal consumption per gross state product PGSP which is the ratio PCONS/GSP decreases because lowering the value of APC can be interpreted as lowering the value of personal consumption, PCONS. Apparently, there is no effect of APC on the values of personal disposable income PDISI, personal income PINCM, the population POP and the per capita agriculture production AGSP. However, the values of AGSP continue to decline due to constant level of agriculture production. It is interesting to observe that with a decrease in the value of APC, there is appreciable decrease in the values of governmental expenditure per gross state product GGSP which is the ratio GEXP/GSP. In other words, it can be stated that if government spending policy continues to remain the same as shown in Figure 9 (which is used as a reference), the proportion of government expenditure would decrease considerably with a slight decrease in the value of APC. Thus, government may wish to reexamine its policy to step up its expenditure with decrease in APC in order to keep up with the same value of proportion GEXP to GSP corresponding to results shown in Figure 9.

2) A decrease in rate of birth BR produced no apparent change in variables under consideration except in the government expenditure per gross state product GGSP. The value of GGSP decreased noticeably.

3) A decrease in 10 per cent in participation rate of labor force PARRT, produced appreciable change in all the variables except in population POP. The decrease in the value of PARRT decreases the value of total labor force TOLF. Since a sizable proportion of TOLF is employed by business sector, the output

Table 2. Comparison of the values of Gross State Product (GSP), Government Expenditure per Gross State Product (GGSP), Business Investment per Gross State Product (BGSP), Personal Consumption per Gross State Product (PGSP), Population POP, Per Capita Agriculture Production (AGSP), Personal Disposable Income (PDISI) and Personal Income (PINCM) at the end of T=40 years (1992), using Figure 2 as a reference.

Variables	Effects on the variables due to		
	7% decrease in APC (Figure 10)	0.4% decrease in BR (Figure 11)	10% decrease in PARRT (Figure 12)
GSP	25% increase	No change	50% decrease
GGSP	99% decrease	6% decrease	192% increase
BGSP	14% increase	No change	31% decrease
PGSP	29% decrease	No change	35% increase
POP	No change	1% decrease	No change
AGSP	No change	1% increase	No change
PDISI	No change	2% increase	31% decrease
PINCM	No change	3% increase	28% decrease

almost 25 per cent increase in gross state product GSP. Qualitatively, this result was expected because with higher savings resulting from lower value of APC, the business investment BGINV increases. However, since GSP appears as denominator in BGSP which is the ratio BGINV/GSP, and because both GSP and BGSP increase with decrease in APC, it follows that BGINV increases faster

GSP=A, GGSP=B, BGSP=D, PGSP=E, BR=K, PDP=R, AGSP=T, PDISI=M, PINCM=N

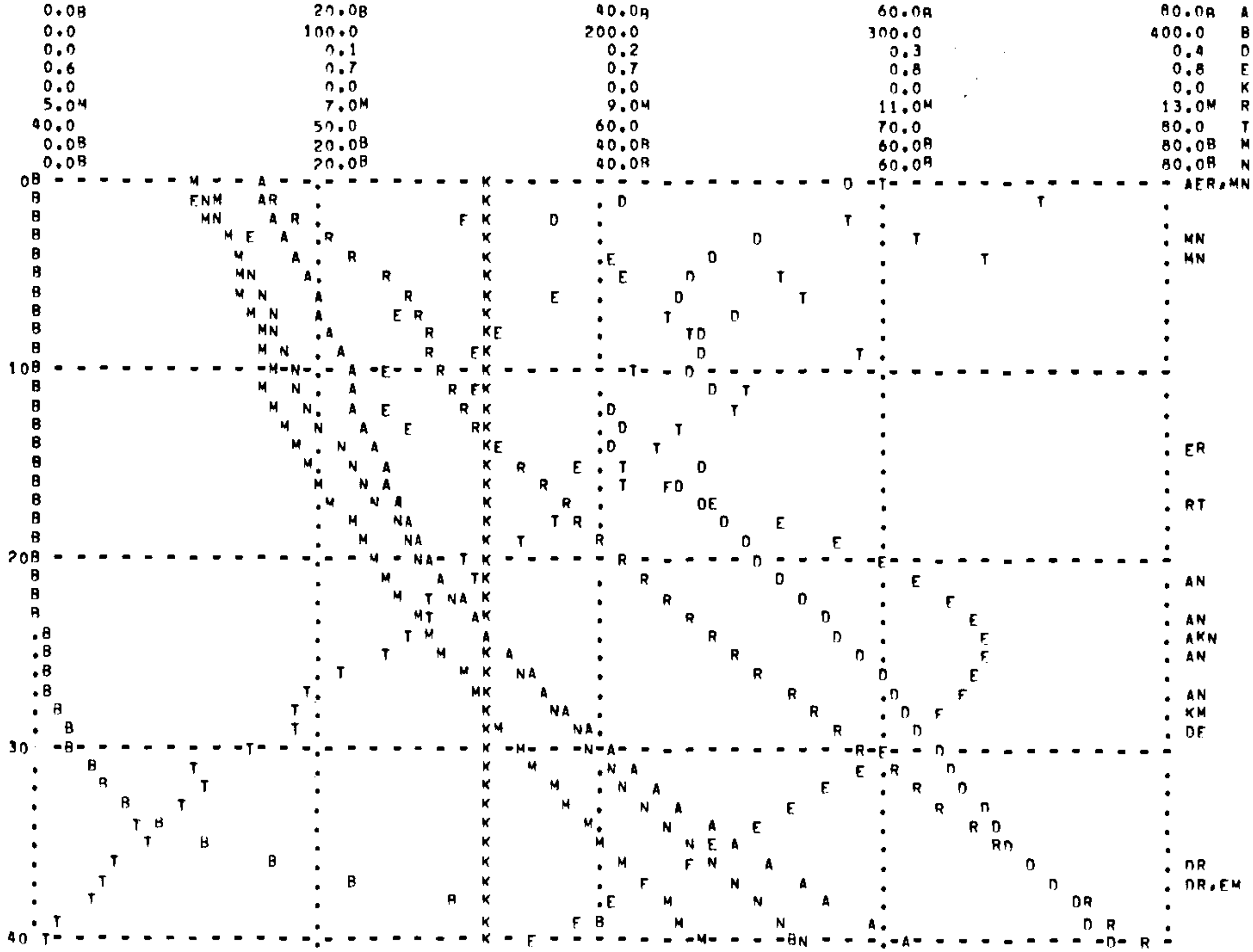


Figure 9. Results Obtained with APC=0.92, PARRT=0.54 and FBR=0.024.

PAGE 13 BEGAN PLOTTING AT 13:01.7892 12 MAY 1970

GSP=A, GGSP=B, BGSP=D, PGSP=E, BR=K, POP=R, AGSP=T, PDISI=M, PINCM=N

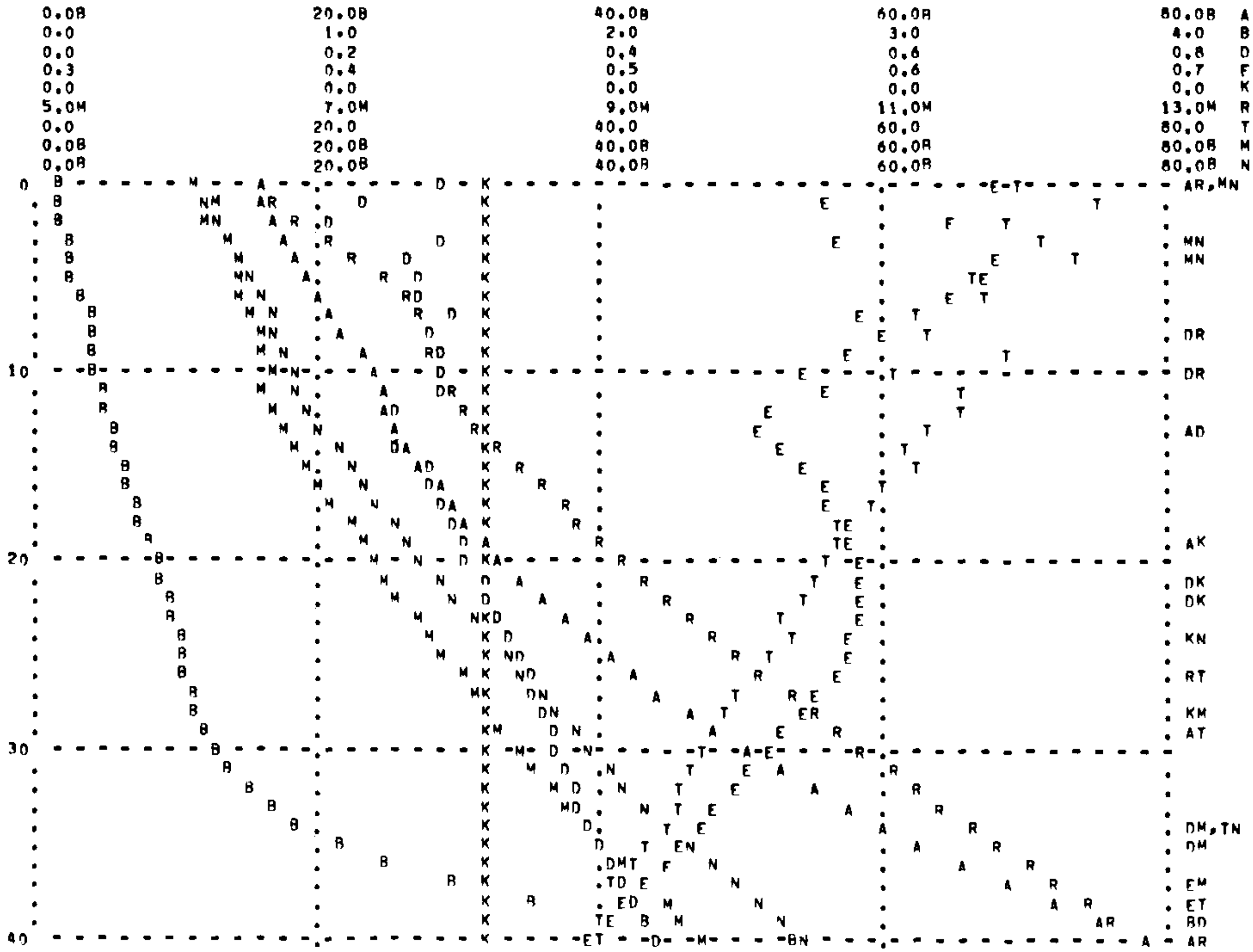


Figure 10. Results Obtained with APC=0.85, PARRT=0.54 and FBR=0.024.

PAGE 20 48 BEGAN PLOTTING AT 13:41.6314 15 MAY 1970

GSP=A, GGSP=B, BGSP=D, PGSP=E, BR=K, PDP=R, AGSP=T, PDISI=M, PINCM=N

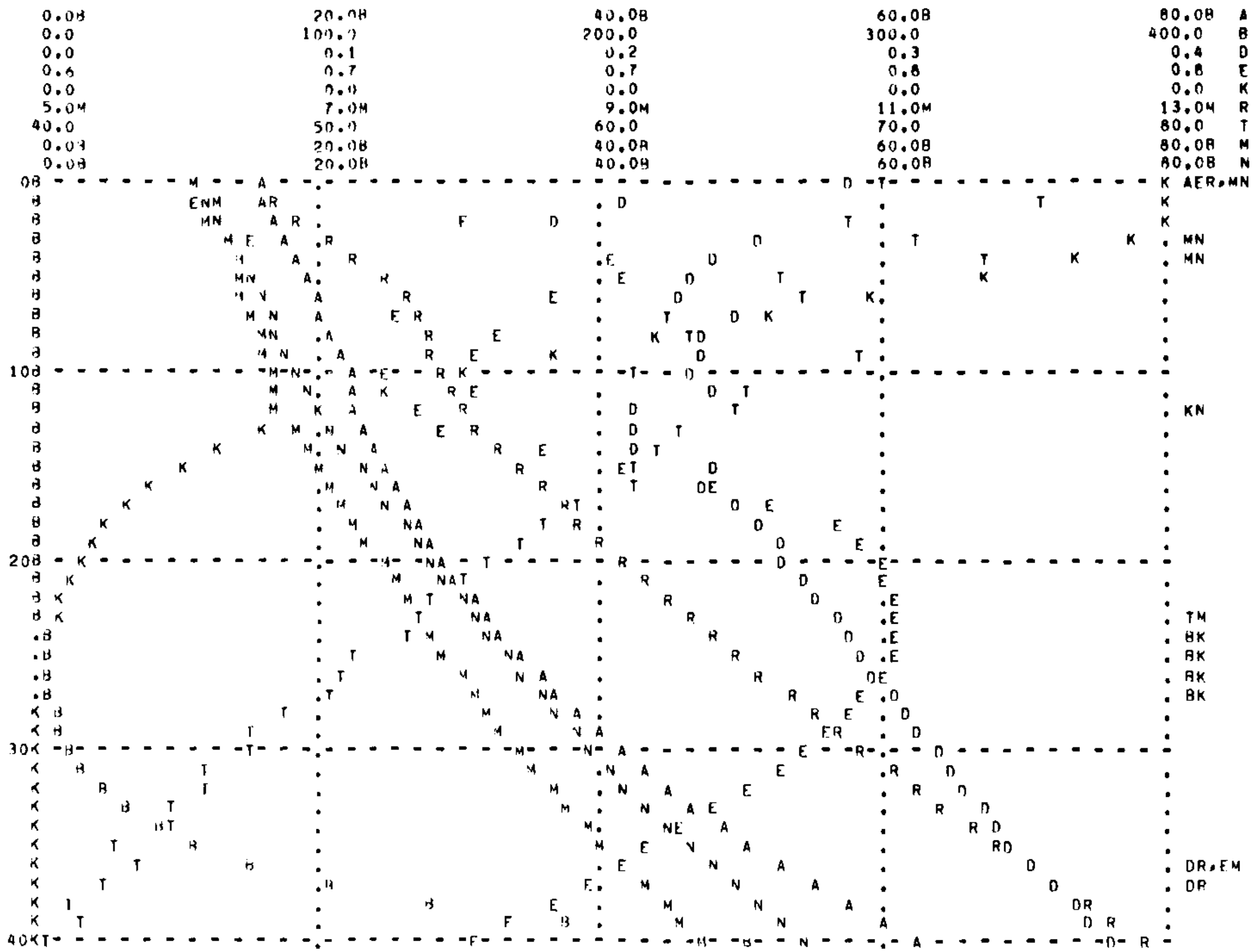


Figure 11. Results Obtained with APC=0.92, PARRT=0.54 and FBR=0.020.

PAGE 27 494 BEGAN PLOTTING AT 13:42.0578 15 MAY 1970

GSP=A, SGSP=B, BGSP=D, PGSP=E, BR=K, PDP=R, AGSP=T, PDISI=M, PINCM=N

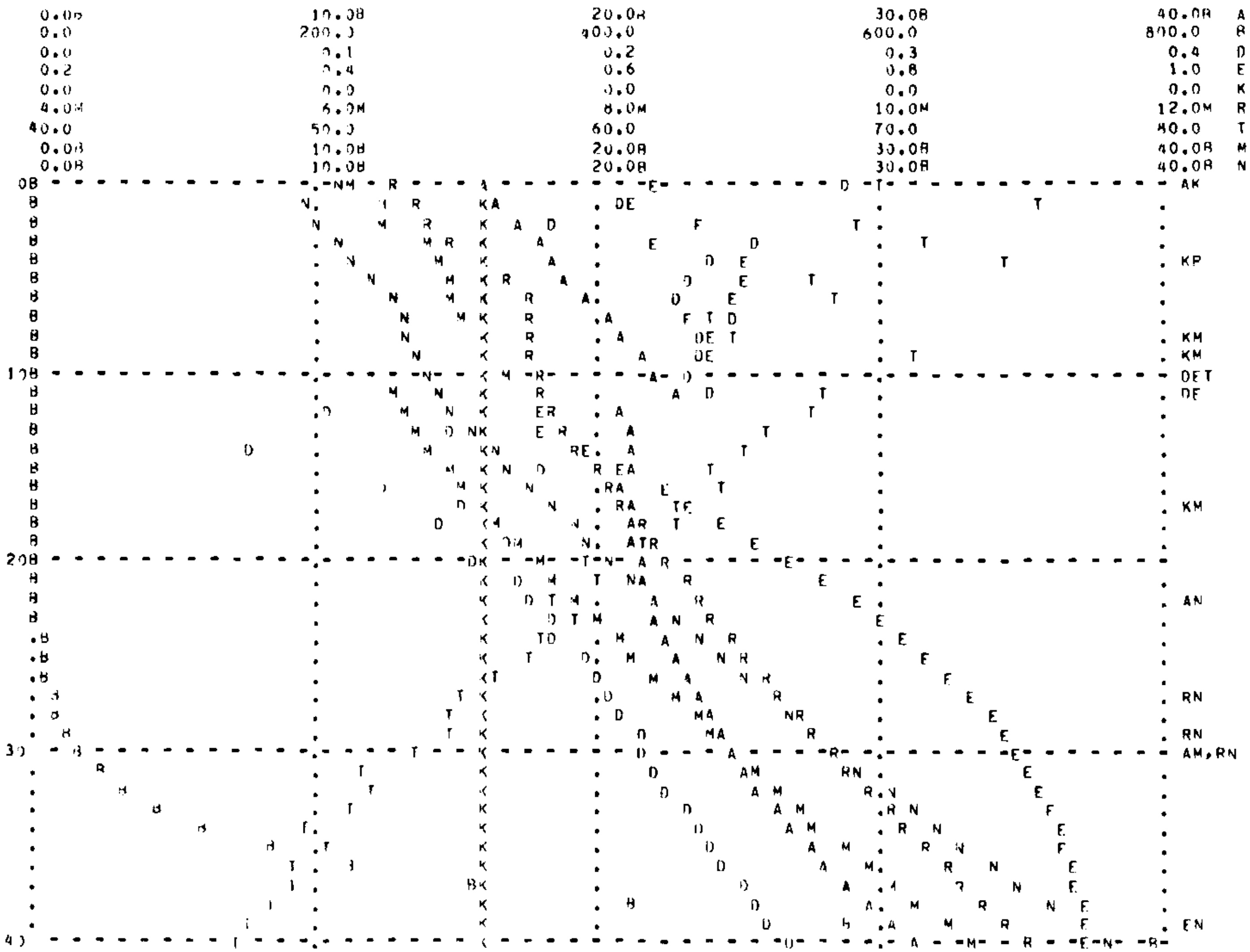


Figure 12. Results Obtained with APC=0.92, PARRT=0.44 and FBR=0.024.

from this sector as measured by Cobb-Douglas function will decrease due to decrease in the value of PARRT. The decrease in output from the business sector will decrease the values of GSP, BGSP, and GGSP.

Model Results: Figures 13 through 16

In these runs, the graphical plots of birth rate BR, per capita values of gross state product GNPO, government expenditures GPOP, business investment BPOP, housing stock HPOP and personal disposable income PPOP are shown. Other two variables shown are total labor force TOLF and the population POP. The results are summarized in Table 3. Figure 13 is used as a reference for comparing the values of the variables shown in the runs represented by Figures 14 through 16.

Table 3. Comparison of the values of Per Capita Gross State Product (GNPO), Per Capita Government Expenditure (GPOP), Per Capita Business Investment (BPOP), Per Capita Housing Stock (HPOP), Per Capita Disposable Income PPOP and Total Labor Force TOLF at the end of T=40 years (1992), using Figure 13 as a reference.

Variables	Effects on the Variables Due to		
	7% decrease in APC (Figure 14)	0.4% decrease in BR (Figure 15)	10% decrease in PARRT (Figure 16)
GNPO	28% increase	1% increase	40% decrease
GPOP	99% decrease	23% decrease	75% increase
BPOP	52% increase	3% increase	58% decrease
HPOP	6% decrease	1% decrease	11% decrease
PPOP	No change	No change	22% decrease
TOLF	No change	1% decrease	31% decrease

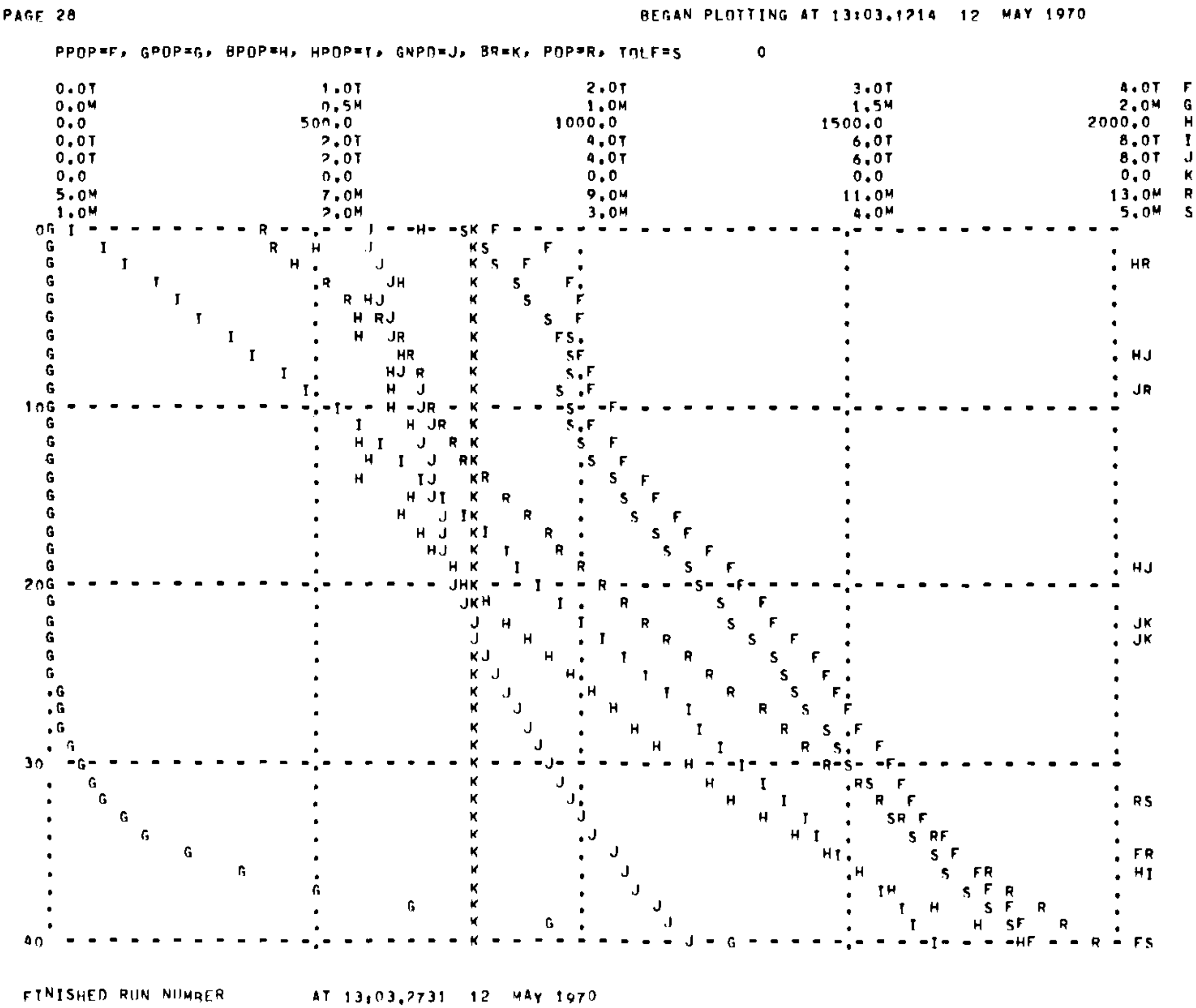
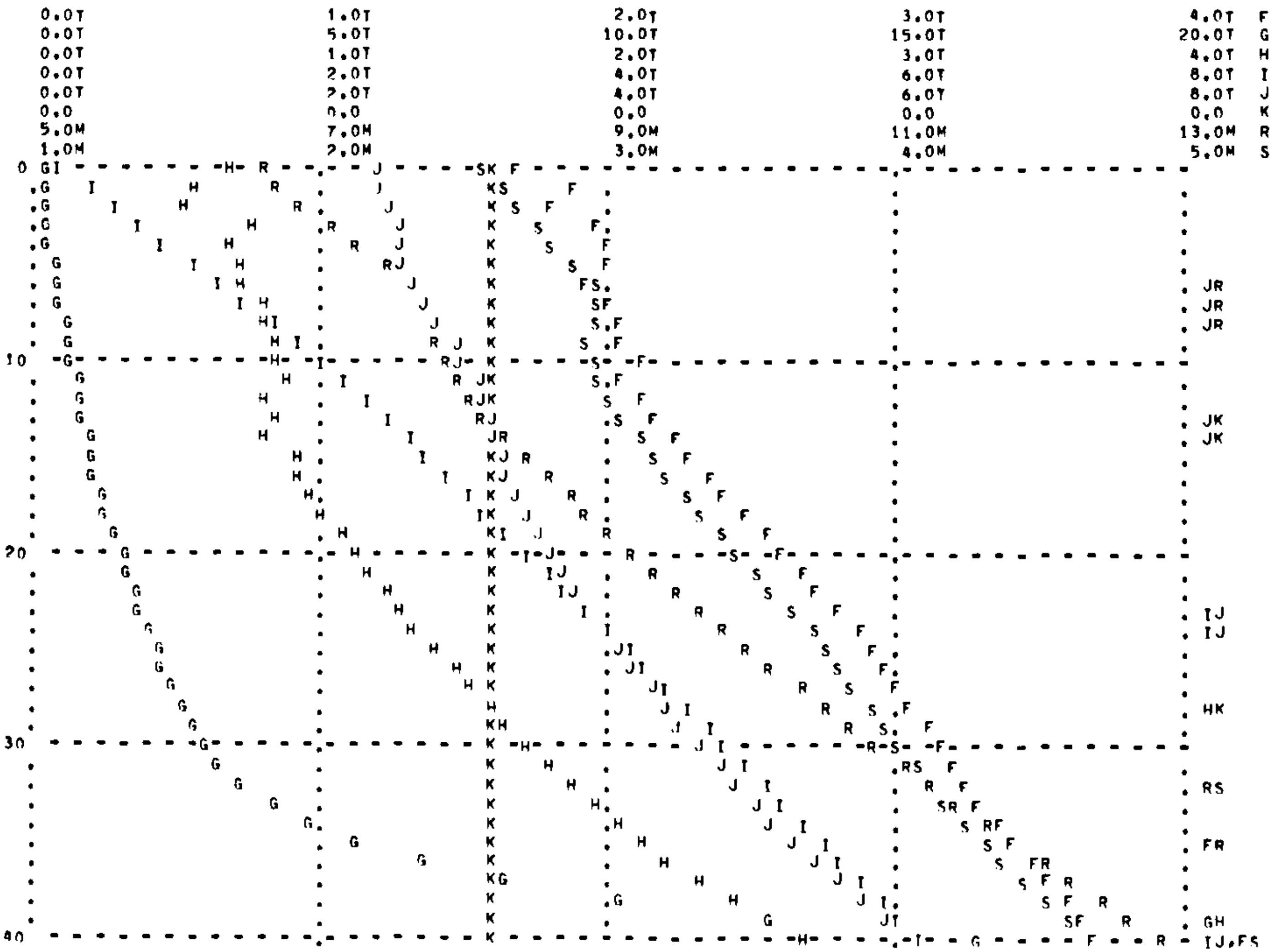


Figure 13. Results Obtained with APC=0.92, PARRT=0.54 and FBR=0.024.

PAGE 14 BEGAN PLOTTING AT 13:01.9261 12 MAY 1970

PPOP=F, GPOP=G, BPOP=H, HPOP=I, GNPO=J, BR=K, POP=R, TOLF=S 0

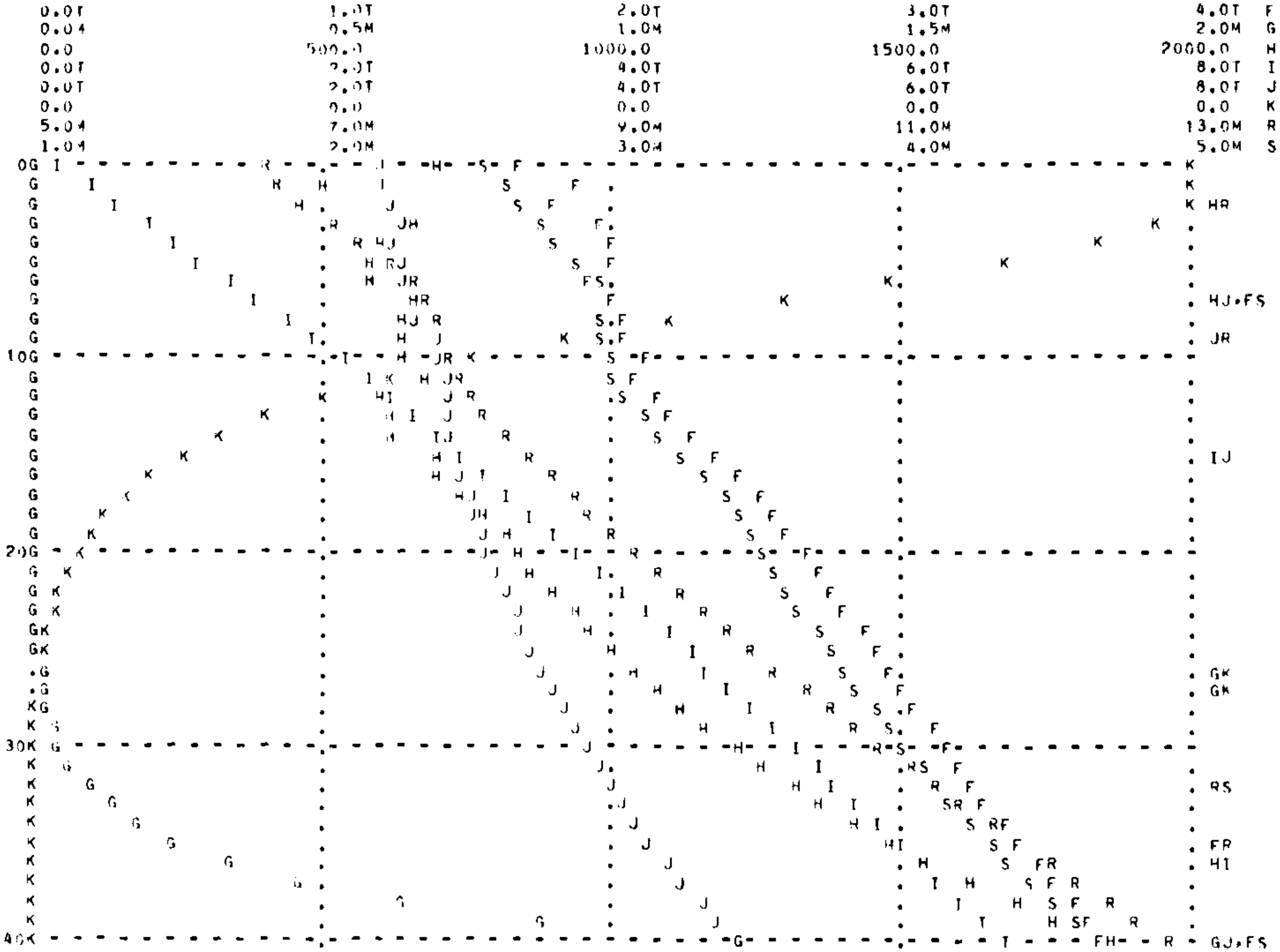


FINISHED RUN NUMBER AT 13:02.0347 12 MAY 1970

Figure 14. Results Obtained with APC=0.85, PARRT=0.54 and FBR=0.024.

PAGE 21 43 BEGAN PLOTTING AT 13:41.7369 15 MAY 1970

PPOP=F, GPOP=G, BPOP=H, HPOP=I, GNPO=J, BR=K, POP=R, TOLF=S 0



FINISHED RUN NUMBER 43 AT 13:41.8464 15 MAY 1970

Figure 15. Results Obtained with APC=0.92, PARRT=0.54 and FBR=0.020.

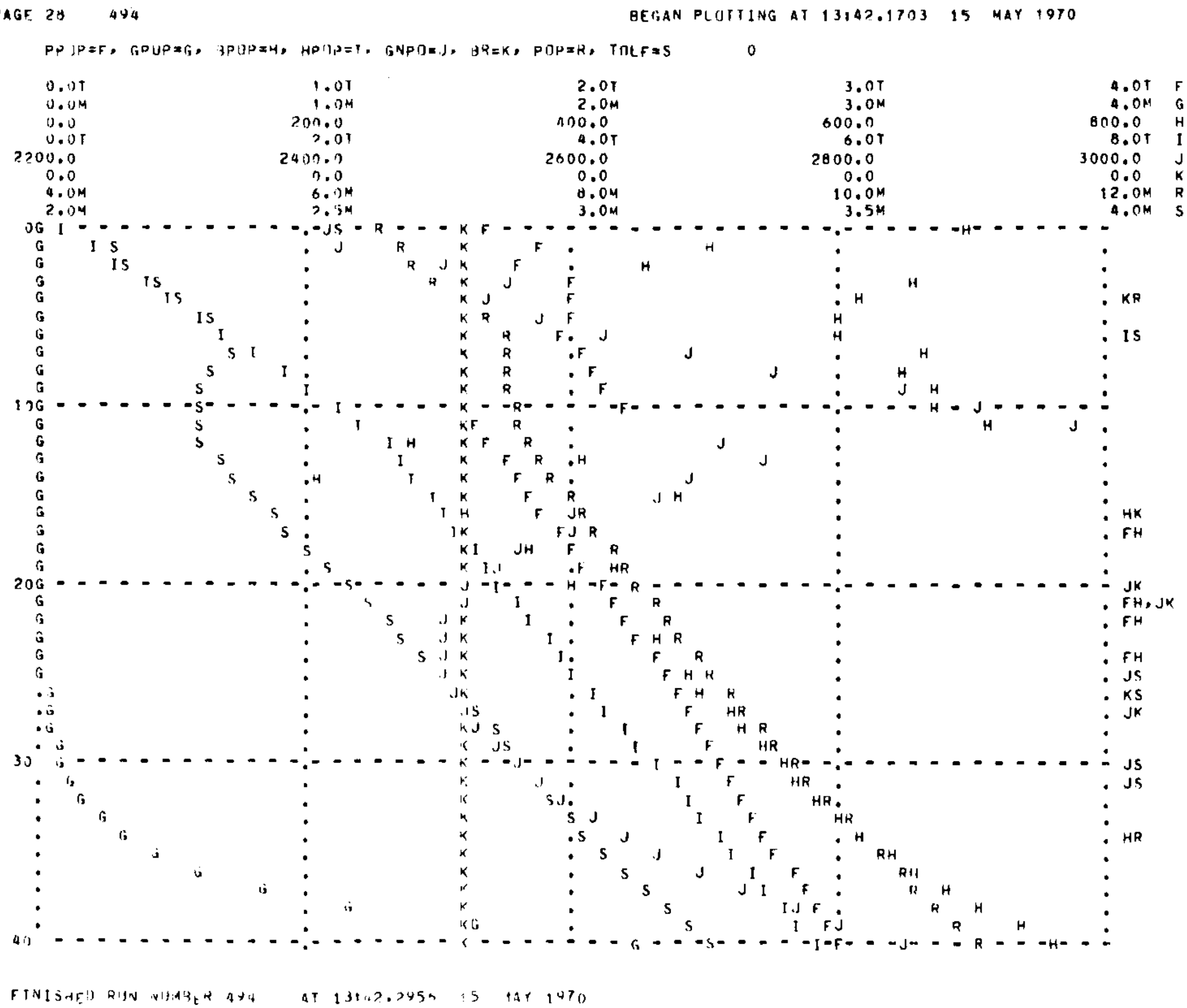


Figure 16. Results Obtained with APC=0.92, PARRT=0.44 and FBR=0.024.

The results shown in Table 3 and Figures 13 through 16 justify the following observations:

1) A decrease in average propensity to consume APC by 7 per cent caused almost four times decrease in the value of per capita gross state product GNPO, almost eight times decrease in the value of per capita business investment BPOP and about the same decrease in the value of per capita housing stock HPOP. The reasons for the decrease in the values of GNPO and BPOP are the same as were given for the decrease in the values of GGSP and BGSP in the discussion of results of Table 2. The value of per capita government expenditure GPOP decreases in magnitude and direction comparable to the value of GGSP as a result of decrease in the value of APC. No apparent change is observed in the per capita values of personal disposable income PPOP due to decrease in the value of APC.

2) A decrease in birth rate by 0.4 per cent caused little change in all the variables except in the value of per capita government expenditures GPOP.

3) A decrease in the value of PARRT by 10 per cent produced appreciable change in the values of all variables except the per capita housing stock HPOP. The variables GNPO, GPOP and BPOP change in the same direction but with different magnitude as was the case with the variables GSP, GGSP and BGSP in the discussion of variables in Table 2. The value of per capita disposable income PPOP decreases about two times the decrease in the value of PARRT.

Model Validation and Experimentation

Ideally, a proposed model should represent the behavior of the actual system for which it was formulated. However, in view of many simplifying assumptions and lack of sufficient insight about the behavior of the system, it is likely that there would be some variation between computed values obtained through the program output and the actual values. On comparing actual values and computed values for some of the significant economic variables, a variation of less than $\pm$ 10 per cent was observed. It does not follow from this result that the model is accurate within the range of $\pm$ 10 per cent. The variation might be due to interaction among many variables of the system and to random economic fluctuations as a result of changing economic policies. The model was simulated for a period of 40 years (1952-1992) which evidently means the model is describing the behavior of the system for past as well as for future periods. In other words, the simulation that is carried out is not only supposed to reproduce the history but also to forecast correctly the behavior of the system variables in order to satisfy the criterion of the validity of the model. However, assessment of model validation based on the forecast by the program cannot be easily made. This difficulty is due to 1) the unpredictable pattern of economic policies, 2) the unavailability of forecast data from reliable sources, and 3) uncertainty regarding the choice of appropriate values of economic parameters for short-run and long-run models. Thus, validation of the model is based upon the correspondence of the output with historical data. Assuming that the same trend will continue in the future, the forecast should be equally valid.

In Table 4 some of the significant economic variables computed by the program are compared with the actual values.

Table 4. Actual and Computed Values of Gross State Product (GSP), Population (POP), T otal Labor Force (TOLF) and Personal Income (PINCM) for the period 1952-1962.

Year / Variable		1952	1954	1956	1958	1960	1962
GSP (billions of dollars)	A	16.538	17.389	19.953	18.597	21.868	23.763
	B	15.892	17.076	18.207	19.629	20.708	22.091
	C	3.9%	1.8%	8.7%	-5.5%	5.0%	7.03%
POP (thous. of people)	A	6707	7134	7533	7686	7823	7939
	B	6571	6839	7255	7634	7761	7895
	C	2.02%	4.13%	3.69%	0.67%	0.79%	0.56%
TOLF (thous. of people)	A	2790	2928	2934	3033	2940	2905
	B	2561	2670	2817	2954	2950	2966
	C	8.23%	8.81%	3.9%	2.62%	-0.34%	2.09%
PINCM	A	12.902	14.127	16.587	16.540	18.137	19.246
	B	10.975	12.429	14.152	15.927	16.997	18.182
	C	14.9%	12.0%	14.7%	3.7%	6.3%	5.5%

Note: A = Actual Values, B = Computed Values, C = Percentage Variation (A-B)(100)/A.

It can be observed from Table 4 that there is close agreement in actual and computed values of gross state product GSP, population POP, and total labor force TOLF. There is, however more variation in personal income which may be attributed to the assumptions on which the population value is computed. In the program, constant values of birth rate and death rate are assumed. It is interesting that the difference between the actual and computed total labor force tends to be smaller with the passage of time.

The model, initially was formulated on the basis of known values of economic parameters such as average propensity to consume (APC=0.92), participation rate (PARRT=0.54) and birth rate (FBR=0.024). These values were held constant during the entire period of simulation. However, in this section the behavior of the model will be tested under different values of the above parameters. The purpose is to explore the nature of system behavior once the parameters are altered. Several runs are obtained for different values of parameters. For a few selected years variables of interest are compared under different sets of parameter values.

The effect of changes in birth rate BR on population POP, total labor force TOLF, gross state product GSP, per capita income PPOP, and business production BPPN are shown in Table 5 for the end of every decade beginning at T=0 (1952) and assuming constant participation rate (PARRT=0.54) and constant average propensity to consume (APC=0.92).

It can be observed from Table 5 that for a given rate of participation of labor force PARRT and average propensity to consume APC, the values of GSP and BPPN moves in parallel with the increasing or decreasing rates of births. However, per capita disposable income tends to decrease with the decrease with the increasing rate of birth and tends to increase with decreasing rate of birth. Also, while the population POP and Total Labor Force TOLF increase or decrease with the rate of birth, the percentage growth of the latter is much less than the growth of the former.

Table 5. Effect of change in birth rate BR on Gross State Product (GSP), Population (POP), Total Labor Force (TOLF), Per Capita Disposable Income (PPOP), and Business Production (BPPN) for constant values of Average Propensity to Consume (APC=0.92) and Participation Rate of Labor Force (PARRT=0.54).

Variables		T				
		0	10	20	30	40
GSP (billion of dollars)	A	15.892	22.091	28.178	40.619	61.578
	B	15.892	22.091	26.959	35.753	49.522
	C	15.892	22.091	29.315	43.967	71.711
POP (millions of people)	A	6.571	7.761	9.173	10.857	12.850
	B	6.571	7.616	8.723	9.673	11.006
	C	6.571	8.183	9.895	12.180	14.993
TOLF (millions of people)	A	2.561	2.950	3.449	4.007	4.683
	B	2.561	2.858	3.261	3.570	4.011
	C	2.561	3.076	3.577	4.333	5.323
PPOP (dollars)	A	1685.3	2042.6	2609.0	3153.1	3699.0
	B	1685.3	2198.1	2662.0	3153.1	3699.0
	C	1685.3	2045.8	2508.0	3039.6	3602.8
BPPN (billion of dollars)	A	15.433	20.278	27.663	40.103	61.056
	B	15.433	20.980	26.444	35.237	44.000
	C	15.433	21.608	28.801	43.450	71.189

Note: T=0 represents 1952; A = constant birth rate of 0.024; B = Decreasing birth rate to 0.020 at the end of 40 years; C = Increasing birth rate to final value of 0.028 at the end of 40 years. The initial value of birth rate in case A and B was 0.024.

During the past two decades, there has been practically no change in the participation rate of the labor force PARRT of 0.54. Table 6 shows the effect on four variables for three different values of PARRT=0.54 and 0.64.

Table 6. Effect of Change in Participation Rate of Labor Force PARRT on Gross State Product (GSP), Total Labor Force (TOLF), Per Capita Disposable Income (PPOP) and Business Production (BPPN) for Constant Values of Birth Rate (BR=0.024) and Average Propensity to Consume (APC=0.092).

Variables	PARRT	T: 0	10	20	30	40
GSP (billions of dollars)	0.44	15.892	22.091	22.788	28.430	39.406
	0.54	15.892	22.091	28.178	40.619	61.578
	0.64	15.892	22.091	33.340	52.907	84.438
TOLF (million of people)	0.44	2.087	2.417	2.810	3.265	3.816
	0.54	2.561	2.950	3.449	4.007	4.683
	0.64	2.035	3.515	4.088	4.749	5.551
PPOP (dollars)	0.44	1685.3	2120.4	2125.9	2569.2	3014.0
	0.54	1685.3	2042.6	2609.0	3153.1	3699.0
	0.64	1685.3	2120.4	3092.2	3737.0	4384.0
BPPN (millions of dollars)	0.44	15.433	21.608	22.274	27.914	38.885
	0.54	15.433	20.278	27.663	40.103	61.056
	0.64	15.433	21.608	32.826	52.390	83.916

Note: T=0 represents 1952.

The effect of the participation rate of labor force PARRT on the four economic variables is substantial. The range of variation in values of the variables is 15 to 30 per cent for a 10 per cent increase or decrease in the participation rate of labor force.

Lastly, the effect of three different values of average propensity to consume APC on economic variables are examined in Table 7. As usual, for the sake of comparison, other two parameters namely: birth rate BR and participation rate of labor force are assumed constant.

Table 7. Effect of Change in Average Propensity to Consume APC on Gross State Product (GSP), Total Labor Force (TOLF), Per Capita Disposable Income (PPOP) and Business Production (BPPN), for Constant Values of Birth Rate (BR=0. 024) and Participation Rate of Labor Force (PARRT=0. 54).

		T				
Variables	APC	0	10	20	30	40
GSP (billions of dollars)	0.86	15.892	23.337	31.840	47.884	74.351
	0.92	15.892	22.091	28.178	40.619	61.578
	0.96	15.892	21.462	26.675	37.810	56.743
TOLF (millions of people)	0.86	2.561	2.966	3.449	4.007	4.683
	0.92	2.561	2.966	3.449	4.007	4.683
	0.96	2.561	2.966	3.449	4.007	7.683
PPOP (dollars)	0.86	1685.3	2120.4	2609.0	3153.1	3699.0
	0.92	1685.3	2042.6	2609.0	3153.1	3699.0
	0.96	1685.3	2120.4	2609.0	3153.1	3699.0
BPPN (billions of dollars)	0.86	15.433	22.855	31.329	47.370	73.839
	0.92	15.433	20.278	27.663	40.103	61.056
	0.96	15.433	20.980	26.168	37.293	56.221

Note: T=0 represents 1952.

The effect of average propensity to consume APC on gross state product GSP and business production BPPN is substantial. Total labor force and per capita disposable income apparently are unaffected by any change in APC.

While the variables of the model are tested for effects of one parameter keeping the other two parameters constant, it is hard to conceive that should one of the parameters change, there is no macroeconomic change on other parameters. In other words, the tests described here have been made with the assumption that there is no interdependence between the values of three parameters, APC, PARRT and BR. However, the model could be tested with other combinations of parameter values.

Sensitivity Analysis

As stated in Chapter II, when parameters of model were set by estimation, the model would be examined for sensitivity to those parameters. Several runs were made while varying one parameter within an appropriate range and the effects on different variables were observed. The analysis revealed that changes in the estimated values did not produce noticeable changes in the variables. Therefore, the model was judged to be not sensitive to the estimated values.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study was concerned with a macroeconomic model of a state economy. The model developed consists of approximately 165 equations which describe the behavior of four sectors of the economy of Michigan.

The model results and experiments presented in Chapter V led the author to several conclusions concerning the behavior of the economy, keeping in mind the assumptions made while the model was developed. These conclusions are summarized below:

1. The results indicated close agreement between the simulated and the actual values of economic variables. This suggests that DYNAMO can be used for simulating a state economic system.
2. The specific simulation results based on three different economic conditions are as follows:
   a. The rate of birth has significant effect on not only population and labor force (TOLF) but also on gross state product (GSP) and business production (BPPN). For a decline in birth rate of 0.4 per cent there was a decline in GSP of 12 per cent and a decline in BPPN of 14 per cent over a period of 40 years.

b. The value of average propensity to consume determines the index of consumption level of goods and services by the population. The lower the value of propensity to consume the higher the magnitude of the personal savings which induces higher investment. A higher investment leads to the increase in the output. Thus, it was observed that gross state product and business production increased by as much as 15-20 per cent with a decrease in average propensity to consume of 5-6 per cent. There was no significant change in per capita personal or disposable income.

c. The labor participation rate in all sectors had an average value of 0.54 from 1950 through 1965. An increase or decrease of the labor participation rate of 20 per cent caused a corresponding change in both GSP and BPPN of about 50 per cent.

3. Both government purchases (GPUR) and government debts (GDEB) increased at a faster rate than the increase of gross state product. However, both purchases and debts increased from year to year by the same proportion except in the case of a government surplus budget when the government debt tends to decline.

4. A decrease in the level of unemployment in the state compared to the rest of the nation caused an increase in the population level as a result of in-migration from other states.

5. Per capita production of agricultural products continued to decline as the population increased because of an almost constant level of annual agricultural output.

Recommendations

It must be realized that models can always be refined, reconstructed or disaggregated in all sectors. A more rigorous approach of macroeconomic principles based on behavioral aspects of the economy can be applied. Many constants and parameters may be revised or reviewed; many variables may be interconnected by virtue of possible interaction among them.

To extend the present research work the following recommendations are suggested:

1) The effects of imports and exports on the state economy should be included to more realistically represent an open system;
2) The intergovernmental transactions should be included;
3) The effects of federal aid, federal tax rates and federal projects carried out in the state should be included;
4) The effects of interstate migration on the labor force skills and the resulting economic effects should be defined;
5) The price levels of the national economic system should be incorporated into the model;
6) The cost of money should be included;
7) The model should be tested for the effects of changes in tax rates and state government expenditures in such areas as education and public utilities.

APPENDIX A

COMPUTER PROGRAM

```
INPUT PHASE BEGIN AT 12:59  1      5/12/70


?COMPILE BIN0833/RSM     *DYNAMO          ,035800012   *0833 MURDIA R S
?PROCESS=        00000015;IO=     00000020,
?COMMON= 008331;FILE DYNAMO= D008331 ;DATA D008331.


              RUN    40

                     POPULATION SECTOR


                     POPULATION AND LABOR FORCE EQUATIONS

              1L     POP.K=POP.J+(DT)(PPGIN.JK+0)                    POPULATION
              N      POP=6571E3
              7A     PPGR.K=POP.K+NMIG.JK
              14R    PPGIN.KL=NMIG.JK+(PINR)(PPGR.K)                 POP GROWTH
              N      PPGIN=136E3
              C      PINR=BR-DR
              C      DR=0.007
              59A    NNT.K=TABLE(NTAB,K,T.K,0,10,1)
              51R    NMIG.KL=CLIP(NMR.K,NNT.K,T.K,11)                NET MIGRATION
              1L     T.K=T.J+(DT)(1+0)                               TIME REFERENCE 1952
              N      T=0
              C      NTAB*=18E3/93E3/84E3/84E3/42E3/-27E3/-105E3/-94E3/-34E3/-82E3/-64E
              X1     3
              18A    UNMDF.K=(CP1)(UNM.K-UNN.K)
              8A     NMR.K=UNMDF.K+MIGF.K+CP3
              18A    MIGF.K=(CP2)(UNM.K-UNN.K)
              C      CP1=-11.18
              C      CP2=-5.54
              C      CP3=-16.29
              12A    PO14O.K=(POPF.K)(POP.K)
              7A     POPFS.K=CA1-POPT.JK
              C      CA1=0.74
              39R    POPT.KL=DELAY3(VAR,30)
              C      VAR=0.1
              N      POPT=0
              56A    POPF.K=MAX(POPFS.K,POPFA.K)
              51A    POPFA.K=CLIP(POFA.K,POFT.K,T.K,11)
              59A    POFT.K=TABLE(PTAB.K,T.K,0,10,1)
              C      PTAB*=.726/.720/.705/.710/.703/.700/.693/.689/.684/.682/.689
              7A     POFA.K=PFC+PFA.K                                POPULATION FACTOR
              C      PFC=0.675
              C      CF1=-0.265
              C      CF2=10
              28A    PFA.K=(PFC)EXP(PA.K)
              18A    PA.K=(CF1)(T.K+CF2)
              37R    BX1=BOXLIN(14,1)
              12A    BX1*1.K=(BR)(POP.K)
              N      BR=0.024
              39R    BR.KL=DELAY3(FBR,10)                            BIRTH RATE
              C      FBR=0.024
              C      BX1*=164E3/162E3/159E3/155E3/154E3/153E3/118E3/117E3/121E3/123E3/1
              X1     13E3/103E3/96E3/95E3
              53A    BXSM.K=SUM1(14,BX1.K)                           SUM POPULATION UND 14
              14A    PO14A.K=POP.K+(-0.997)(BXSM.K)
              54A    PO14.K=MIN(PO14O.K,PO14A.K)                     POP OVER 14
              12A    TOLF.K=(PARRT)(PO14.K)                          TOTAL LABOR FORCE
              C      PARRT=0.54                                      PARTICIPATION RATE
```

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        PERSONAL/HOUSEHOLD EQUATIONS

14A     WAGE.K=INWA+(INCRW.K)(T.K)                          WAGE RATE
C       INWA=2.09                                           INITIAL WAGE
56R     INCRW.K=MAX(INCW.K,.09)                             INCREASE IN WAGE
17A     INCW.K=(0.5)(IMDG.K)(GRW.K)+(-0.5)(IMDG.J)(GRW.K)+(0)(0)(0)+(0)(0)(0)
56A     GRW.K=MAX(GW1.K,1)
22A     GW1.K=(1/GSP.J)((50)(GSP.K)+(-50)(GSP.J))
51A     IMDG.K=CLIP(IND.K,ING.K,T.K,11)                     INFLATION COEFFICIENT
59A     ING.K=TABLE(INH.K,T.K,0,10,1)
C       INH*=96.8/98.7/100.0/101.2/104.8/109.2/111.9/113.7/115.7/117.4/118
X1      .2
14A     IND.K=INF.J+(INIF)(INF.J)                           PROJECTED INFLATION COEF.
6N      INF=118.2
C       INIF=0.012
51A     PDIST.K=CLIP(PDR.K,PDR.K,T.K,11)                    PERS. DISP. INCOME
59A     PDR.K=TABLE(PD.K,T.K,0,10,1)
C       PD*=11076E6/12540E6/12369E6/13873E6/14483E6/14781E6/14648E6/15383E
X1      6/15852E6/15873E6/16741E6
12A     PDR.K=(TAXF)(PINCM.K)
12A     PINCM.K=(TOLF.K)((2050)(WAGE.K))                    PERSONAL INCOME
C       TAXF=0.87                                           TAX FACTOR
1L      PCONS.K=PCONS.J+(DT)((APC)(PDIST.K)-PCONS.J) PERS. CONSUMPTION
N       PCONS=10180E6
C       APC=0.92                                            AVER. PROP. TO CONS.
7A      PSAV.K=PDIST.K-PCONS.K                              PERSONAL SAVING
1L      PSAC.K=PSAC.J+(DT)(PSAV.K)                          PERSONAL SAVING ACCT.
N       PSAC=911E6
12A     PINH.K=(CIN)(PCONS.K)                               PERSONAL INVES. IN HOUSING
C       CIN=0.15
1L      PHST.K=PHST.J+(DT)(PINH.JK-HDEP.JK)                 HOUSING STOCK
N       PHST=940E6
12R     HDEP.KL=(HC)(PHST.K)                                HOUSING DEPRECIATION
C       HC=0.035

        GOVERNMENT SECTOR

8A      GEXP.KL=GWAG.K+GPUR.JK+GINP.K                       GOVT. EXPENSES
N       GEXP=1423E6
12A     GWAG.K=(GLAF.K)((2050)(WAGE.K))                     GOVT. WAGE
1L      GLAF.K=GLAF.J+(DT)(GLIN.JK+0)                       GOVT. LABOR FORCE
N       GLIN=2E3
N       GLAF=106E3
51R     GLIN.KL=CLIP(GL,GT.K,T.K,11)                        GOVT. LABOR INCREASE
59A     GT.K=TABLE(GTAB.K,T.K,0,10,1)
C       GTAB*=0/7E3/2E3/5E3/193E3/2.5E3/4.8E3/4.4E3/8.0E3/4.2E3/4.3E3
C       GL=4E3
1L      GSER.K=GSER.J+(DT)(GSIN.JK+0)                       GOVT. PUBLIC SERVICE
N       GSIN=300E6
54R     GSIN.KL=MIN(PS.K,PN.K)
12A     PS.K=(0.1)(GPUR.JK)
13A     PN.K=(1+(GW1.K))(POP.K)(80)
N       GSER=500E6
12A     GINV.K=(GKN)(GPUR.JK)                               GOVT. INVESTMENT
C       GKN=0.4
8A      GPUR.KL=GINV.K+GSER.K+GBBF.K                        GOVT. PURCHASES
N       GPUR=1187E6
12A     GINP.K=(INT)(GDEB.K)                                GOVT. INTEREST PAYMENT
3L      GDEB.K=GDEB.J+(DT)(1/DFB)(GEXP.JK-GTAX.K)  GOVT. DEBTS
C       INT=0.03                                            INTEREST RATE
N       GDEB=335.3E6
```

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56A    GBUF.K=MAX((BDS.K-BPS.K),0)                    GOVT. BUFFER PURCHASES
C      DEB=5
12A    GTAX.K=(GSP.K)(0.1)                            GOVT. TAX COLLECTION

       BUSINESS/NON AGRICULTURE SECTOR

51R    BLAF.K=CLIP(BEL.K,BLE.K,T.K,11)                BUSINESS LABOR FORCE
1L     BLE.K=BLE.J+(DT)(BLINC.JK+0)
N      BLE=2517E3
59A    BLINC.KL=TABLE(BTAB,K,T.K,0,10,1)              BUSINESS LAB FORCE INC.
C      BTAB*=0/147E3/-13E3/-14E3/19E3/31E3/-58E3/-3E3/-7E3/-17E3/0
16A    BEL.K=(TOLF.K)(1-(0.01)(UNM.K))+(-GLAF.K)(1)+(-ALAF.K)(1)
1L     BPPN.K=BPPN.J+(DT)(BPR.K-(0.980)(BPPN.J))   BUSINESS POSSIBLE PRODUCTION
N      BPPN=15433E6
12A    BPR.K=((FLABF.K)(B1))(FCAPF.K)
C      B1=1E6
29A    LABF.K=(LA)LOGN((BLAF.K)(BP2))
C      BP2=1E-3
29A    CAPF.K=(AP)LOGN((BCSK.K)(BP1))
C      BP1=1E-6
28A    FLABF.K=EXP(LABF.K)
28A    FCAPF.K=EXP(CAPF.K)
C      LA=0.3
C      AP=0.7
14A    BPS.K=STK.K+(PM)(BPPN.K)                       BUSINESS POSSIBLE SALES
8A     BDS.K=GPUR.JK+PCONS.K+((AGPR.K)(0.1))          BUSINESS SALES DESIRED
C      PM=0.95
1L     STK.K=STK.J+(DT)(BPPN.K-BASL.K)                STOCK LEVEL IN BUSINESS
6A     BASL.K=BPS.K                                   ACTUAL SALES IN BUSINESS
N      STK=(0.04)(BPPN)
11A    BEPN.K=BPPN.K+(BL4*1.K-BL4*4.K)/3              EXPEC. PRODN. IN BUSINESS
37R    BL4=BOXLIN(4,1)
6A     BL4*1.K=BPPN.K
C      BL4**17959E6/15696E6/16923E6/15433E6
46A    INTVB.K=(BCSK.K)(BEPN.K-BPPN.K)(1.5)/((BPPN.K)(1)(1))
7A     BINV.K=BDPR.JK+INTVB.K                         INVESTMENT IN BUSINESS
9A     BCAP.K=BPS.K-PCONS.K-GPUR.JK-BINV.K            CAPACITY INCREASE IN BUSINESS
11A    BGINV.K=BINV.K+MAX(BCAP.K/2,0)                 GROSS LEVEL OF BUSINESS INVEST
1L     BCSK.K=BCSK.J+(DT)(BGINV.JK-BDPR.JK)           CAPITAL STOCK IN BUSINESS
N      BCSK=33523E6
12R    BDPR.KL=(0.055)(BCSK.K)                        DEPRECIATION IN BUSINESS
11A    BRER.K=(0.08)(BASL.K)                          RETAINED EARNING IN BUSINESS
1L     BSAV.K=BSAV.J+(DT)(BRER.K-BGINV.K)             SAVING IN BUSINESS
N      BSAV=500E6

       AGRICULTURE SECTOR

1L     ALAF.K=ALAF.J+(DT)(AGILF.JK+0)                 AGRICULTURE LABOR FORCE
N      ALAF=141E3
51R    AGILF.KL=CLIP(ALN.K,ALC.K,T.K,11)              INCREASE IN AGRI. LAB. FORCE
59A    ALC.K=TABLE(ATAB,K,T.K,0,10,1)
C      ATAB*=-4E3/-6E3/-2E3/-2E3/-6E3/-8E3/-7E3/-6E3/-7E3/-3E3/-4E3
6A     ALN.K=-ALD.JK
14R    ALD.KL=-ALR+(ALR)(ALM.K)
28A    ALM.K=EXP(S.K)
48A    S.K=1/(T.K+1)
C      ALR=40E3
1L     AGPR.K=AGPR.J+(DT)(AGOT.JK-(0.970)(AGPR.J))  AGRICULT. PRODUCTION
N      AGPR=459E6
51R    AGOT.KL=CLIP(AGN.K,AGI.K,T.K,11)               AGRICULTURE OUTPUT
59A    AGI.K=TABLE(AGTB.K,T.K,0,10,1)
C      AGTB*=492E6/456E6/487E6/519E6/481E6/497E6/467E6/476E6/524E6/466E6/
```

```
X1      500E6
34R     AGN.K=(AGAOT)NORMRN(1,0,01)
C       AGAOT=500E6                                        AVER. AGRI. OUTPUT
6A      UNM.K=6                                            UNEMPLOYMENT STATE
6A      UNN.K=5                                            UNEMPLOYMENT NATIONAL LEVEL
7A      GSP.K=AGPR.K+BPPN.K                                GROSS STATE PRODUCT
20R     GGSP.KL=GEXP.JK/GSP.K
20R     BGSP.KL=BGINV.K/GSP.K
20R     PGSP.KL=PCONS.K/GSP.K
20R     PPOP.KL=PDIST.K/POP.K
20R     GPOP.KL=GEXP.JK/POP.K
20R     HPOP.KL=PHST.K/POP.K
20R     BPOP.KL=BGINV.K/POP.K
20R     GNPO.KL=GSP.K/POP.K
20R     AGSP.KL=AGPR.K/POP.K
PRINT   1)GSP,GGSP,BGSP/2)PGSP,PPOP,GPOP/3)BPOP,HPOP,GNPO/4)AGSP,WAGE,POP/
X1      5)PDIST,PO14O,PO14A/6)PO1A,BR,AGOT/7)TOLF,GWAG,GLAF/8)BLAF,ALAF,BP
X2      PN/9)AGPR,PINCM,GPUR/10)BCSK,GDEB,STK/11)BPS,BDS,PCONS
PLOT    GSP=A/GGSP=B/BGSP=D/PGSP=F/BR=K/POP=R/AGSP=T/PDISI=M/PINCM=N
PLOT    PPOP=F/GPOP=G/BPOP=H/HPOP=I/GNPO=J/BR=K/POP=R/TOLF=S
SPEC    DT=1/LENGTH=40/PRTPER=1/PLTPER=1
RUN
C       APC=0.85
RUN
C       APC=0.90
RUN
C       APC=0.92

INPUT PHASE CONCLUDED AT  12:59 17
                                                    ESTIMATED PRT REQUIREMENT = 666

GENERATION PHASE BEGAN AT 12:59 17
RUN  PHASE  GENERATED AT  12:59 36
PRINT PHASE GENERATED AT  12:59 38
PLOT PHASES GENERATED AT  12:59 41

ELAPSED COMPILATION TIME      0 42
```

APPENDIX B

A SAMPLE OUTPUT

TIME	GSP	PGSP	BPOP	AGSP	PDISI	PO14	TOLF	BLAF	AGPR	BCSK	BPS
	GGSP	PPOP	HPOP	WAGE	PO14O	BR	GWAG	ALAF	PINCM	GDEB	BDS
	BGSP	GPOP	GNPO	POP	PO14A	AGOT	GLAF	BPPN	GPUR	STK	PCONS
E+00	E+06	E+00	E+00	E+00	E+06	E+03	E+03	E+03	E+06	E+09	E+06
	E+00	E+00	E+00	E+00	E+03	E-03	E+06	E+03	E+06	E+09	E+09
	E+00	E+03	E+00	E+03	E+03	E+06	E+03	E+06	E+09	E+06	E+06
0.000	15892.	0.64057	698.1	69.852	11074.	4743.5	2561.5	2517.0	459.00	33.52	15279.
	0.09	1685.3	143.1	2.0900	4862.5	24.000	454.2	141.00	10975.	0.	11.
	0.28865	0.2	2418.5	6571.	4743.5	492.00	106.00	15433.	1.	617.3	10180.
1.000	16232.	0.62767	507.7	75.409	12540.	4882.5	2636.6	2517.0	505.77	36.27	16004.
	0.09	1869.7	362.9	2.1800	4963.2	24.000	482.7	137.00	11783.	0.	11.
	0.20979	0.2	2420.1	6707.	4882.5	456.00	108.00	15726.	1.	1064.5	10188.
2.000	17076.	0.67563	457.7	68.892	12369.	4945.9	2670.8	2664.0	471.17	37.68	17439.
	0.10	1808.5	566.9	2.2700	5061.1	24.000	535.2	131.00	12429.	0.	13.
	0.18332	0.2	2496.7	6839.	4945.9	487.00	115.00	16604.	1.	1664.9	11537.
3.000	17851.	0.63746	650.3	71.081	13873.	5083.8	2745.2	2651.0	501.14	38.74	18059.
	0.10	1967.8	776.1	2.3600	5217.1	24.000	566.0	129.00	13281.	0.	13.
	0.25683	0.3	2532.1	7050.	5083.8	519.00	117.00	17350.	2.	1576.1	11379.
4.000	18207.	0.70100	606.4	73.604	14483.	5218.1	2817.8	2637.0	534.03	41.19	17979.
	0.11	1996.2	963.0	2.4500	5368.3	24.000	612.7	127.00	14152.	0.	14.
	0.24163	0.3	2509.4	7255.	5218.1	481.00	122.00	17673.	2.	1190.1	12763.
5.000	18909.	0.70466	588.4	66.587	14781.	5361.0	2894.9	2656.0	497.02	43.32	19114.
	0.12	1980.2	1159.8	2.5400	5520.8	24.000	1640.2	121.00	15074.	0.	15.
	0.23227	0.3	2533.3	7464.	5361.0	497.00	315.00	18412.	2.	1622.8	13324.
6.000	19629.	0.69278	586.5	67.058	14648.	5470.5	2954.1	2687.0	511.91	45.33	19787.
	0.18	1918.8	1356.2	2.6300	5642.5	24.000	1711.8	113.00	15927.	1.	16.
	0.22811	0.5	2571.3	7634.	5470.5	467.00	317.50	19117.	2.	1625.7	13599.
7.000	20286.	0.66432	651.3	62.351	15383.	5508.4	2974.5	2629.0	482.36	47.32	20455.
	0.19	1988.5	1555.1	2.7200	5712.5	24.000	1797.1	106.00	16586.	1.	16.
	0.24837	0.5	2622.2	7736.	5508.4	476.00	322.30	19803.	3.	1642.0	13476.
8.000	20768.	0.68145	630.2	63.198	15852.	5464.1	2950.6	2626.0	490.47	49.75	20728.
	0.20	2042.6	1756.3	2.8100	5723.1	24.000	1882.0	100.00	16997.	2.	17.
	0.23551	0.5	2676.0	7761.	5464.1	524.00	326.70	20278.	3.	1464.5	14152.
9.000	21530.	0.67738	648.1	69.091	15873.	5431.5	2933.0	2619.0	538.71	51.91	21669.
	0.21	2035.7	1959.2	2.9000	5740.2	24.000	1989.8	93.00	17437.	2.	18.
	0.23472	0.6	2761.2	7797.	5431.5	466.00	334.70	20991.	3.	1727.4	14584.
10.000	22091.	0.66106	647.9	61.070	16741.	5493.1	2966.3	2602.0	482.16	54.11	22195.
	0.23	2120.4	2144.3	2.9900	5800.6	24.000	2077.3	90.00	18182.	3.	18.
	0.23155	0.6	2798.0	7895.	5493.1	504.00	338.90	21608.	4.	1666.9	14603.

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TIME	GSP GGSP BGSP	PGSP PPOP GPOP	BPOP HPOP GNPO	AGSP WAGE POP	POIST PO14O PO14A	PO14 BR AGOT	TOLF GWAG GLAF	BLAF ALAF BPPN	AGPR PINCM GPUR	BCSK GDER STK	BPS BDS PCONS
11.000	22721.	0.67786	681.3	65.248	16336.	5507.3	2973.9	2366.3	518.46	56.25	22767.
	0.25	2055.9	2331.7	3.0800	5824.3	24.000	2167.0	86.00	18777.	3.	19.
	0.23828	0.7	2859.4	7946.	5507.3	503.83	343.20	22202.	4.	1674.5	15402.
12.000	22705.	0.66196	582.5	64.793	16914.	5540.0	2991.6	2382.7	519.38	58.57	22169.
	0.27	2110.0	2518.6	3.1700	5860.1	24.000	2256.3	82.19	19441.	4.	20.
	0.20567	0.8	2832.4	8016.	5540.0	496.75	347.20	22185.	5.	1092.8	15029.
13.000	23368.	0.66590	595.9	62.846	17707.	5639.7	3045.4	2432.8	512.33	60.01	23492.
	0.29	2172.0	2666.4	3.2600	5942.3	24.000	2347.1	78.72	20353.	5.	21.
	0.20790	0.8	2866.4	8152.	5639.7	498.38	351.20	22855.	6.	1779.4	15561.
14.000	23912.	0.68127	587.9	61.966	18524.	5741.4	3100.4	2483.6	513.75	61.57	23914.
	0.32	2234.3	2811.6	3.3500	6024.2	24.000	2439.3	75.52	21292.	6.	22.
	0.20382	0.9	2884.1	8291.	5741.4	495.65	355.20	23398.	7.	1685.5	16290.
15.000	24480.	0.69615	680.0	60.612	19352.	5841.0	3154.2	2533.2	511.06	63.06	24512.
	0.34	2295.1	2957.6	3.4400	6105.9	24.000	2533.1	72.56	22243.	7.	24.
	0.23420	1.0	2903.4	8432.	5841.0	505.84	359.20	23969.	7.	1741.2	17042.
16.000	25040.	0.71100	662.9	60.778	20204.	5942.8	3209.1	2583.6	521.17	65.32	25041.
	0.37	2356.1	3104.5	3.5300	6187.7	24.000	2628.3	69.80	23223.	9.	25.
	0.22700	1.1	2920.1	8575.	5942.8	498.71	363.20	24519.	9.	1747.9	17803.
17.000	25791.	0.72069	699.3	58.979	21088.	6048.6	3266.2	2635.8	514.34	67.42	25997.
	0.40	2418.1	3252.0	3.6200	6269.6	24.000	2725.0	67.22	24239.	10.	27.
	0.23646	1.2	2957.5	8721.	6048.6	504.27	367.20	25277.	11.	1984.3	18588.
18.000	26517.	0.73162	725.1	58.598	22004.	6158.2	3325.4	2689.9	519.70	69.81	26682.
	0.44	2481.0	3400.1	3.7100	6351.8	24.000	2823.2	64.80	25292.	12.	31.
	0.24252	1.3	2989.9	8869.	6158.2	501.20	371.20	25998.	15.	1984.6	19401.
19.000	27318.	0.74103	767.5	57.296	22953.	6271.7	3386.7	2745.8	516.79	72.40	27565.
	0.52	2544.7	3548.9	3.8000	6434.5	24.000	2922.8	62.51	26383.	14.	35.
	0.25339	1.6	3028.7	9020.	6271.7	490.84	375.20	26801.	21.	2103.4	20243.
20.000	28170.	0.74962	788.3	55.200	23933.	6388.2	3449.6	2803.1	506.35	75.34	28483.
	0.66	2609.0	3698.5	3.8900	6517.8	24.000	3023.9	60.35	27509.	18.	43.
	0.25671	2.0	3070.9	9173.	6388.2	501.88	379.20	27663.	31.	2202.3	21117.
21.000	29138.	0.75566	829.4	55.426	24938.	6506.0	3513.2	2860.9	517.07	78.43	29530.
	0.86	2673.2	3848.9	3.9800	6602.0	24.000	3126.5	58.30	28664.	22.	53.
	0.26554	2.7	3123.4	9329.	6506.0	495.57	383.20	28621.	45.	2340.3	22018.
22.000	30129.	0.76150	864.8	53.869	25962.	6623.2	3576.5	2918.4	511.09	81.85	30565.
	1.16	2736.4	4000.3	4.0700	6687.2	24.000	3230.6	56.35	29841.	28.	68.
	0.27234	3.7	3175.6	9487.	6623.2	506.71	387.20	29618.	65.	2428.0	22943.

TIME	GSP	PGSP	BPOP	AGSP	PDIST	PD14	TOLF	BLAF	AGPR	BCSK	BPS
	GGSP	PPOP	HPOP	WAGE	PD140	BR	GWAG	ALAF	PINCM	GDFR	BDS
	BGSP	GPOP	GNPO	POP	PD14A	AGDT	GLAF	BPPN	GPUR	STK	PCONS
23.000	31221.	0.76503	904.9	54.105	27004.	6740.2	3639.7	2975.6	522.04	85.55	31725.
	1.57	2798.7	4152.4	4.1600	6773.5	24.000	3336.2	54.49	31039.	38.	89.
	0.27965	5.1	3235.7	9649.	6740.2	505.08	391.20	30699.	94.	2561.8	23885.
24.000	32370.	0.76751	942.2	53.068	28072.	6858.3	3703.5	3033.4	520.74	89.58	32942.
	2.15	2860.8	4305.2	4.2500	6861.0	24.000	3443.2	52.71	32267.	51.	119.
	0.28561	7.1	3298.7	9813.	6858.3	507.65	395.20	31849.	135.	2685.2	24844.
25.000	33603.	0.76856	986.1	52.435	29050.	6950.0	3753.0	3077.6	523.28	93.90	34250.
	2.95	2910.9	4458.5	4.3400	6950.0	24.000	3551.7	51.01	33390.	70.	161.
	0.29285	9.9	3367.2	9980.	6976.4	501.34	399.20	33080.	193.	2823.6	25826.
26.000	34855.	0.76678	1023.5	50.944	30038.	7040.5	3801.9	3121.2	517.04	98.57	35532.
	4.04	2959.7	4612.3	4.4300	7040.5	24.000	3661.7	49.38	34527.	98.	220.
	0.29803	13.9	3434.3	10149.	7095.0	496.39	403.20	34338.	274.	2911.7	26726.
27.000	36187.	0.76367	1063.3	49.595	31050.	7132.8	3851.7	3165.6	511.90	103.54	36947.
	5.51	3008.3	4764.9	4.5200	7132.8	24.000	3773.1	47.81	35690.	137.	302.
	0.30327	19.3	3506.0	10322.	7215.6	500.42	407.20	35676.	388.	3054.8	27635.
28.000	37597.	0.75981	1101.8	49.135	32086.	7226.8	3902.5	3210.8	515.77	108.82	38416.
	7.50	3056.6	4916.1	4.6100	7226.8	24.000	3886.0	46.30	36880.	192.	417.
	0.30761	26.9	3581.6	10497.	7338.2	508.06	411.20	37081.	548.	3189.0	28566.
29.000	39082.	0.75532	1147.1	49.041	33146.	7322.7	3954.3	3257.0	523.53	114.40	39961.
	10.18	3104.9	5066.2	4.7000	7322.7	24.000	4000.5	44.84	38099.	271.	578.
	0.31334	37.3	3660.9	10675.	7463.0	501.24	415.20	38558.	772.	3331.2	29519.
30.000	40620.	0.75074	1191.4	47.614	34233.	7420.7	4007.2	3304.1	516.95	120.35	41570.
	13.79	3153.1	5215.0	4.7900	7420.7	24.000	4116.3	43.44	39348.	382.	803.
	0.31845	51.6	3741.4	10857.	7589.8	490.06	419.20	40103.	1086.	3472.7	30495.
31.000	42237.	0.74566	1238.8	45.788	35347.	7520.7	4061.2	3352.2	505.57	126.67	43279.
	18.55	3201.3	5362.6	4.8800	7520.7	24.000	4233.7	42.08	40628.	539.	1118.
	0.32383	71.3	3825.3	11041.	7718.8	499.34	423.20	41732.	1526.	3634.0	31494.
32.000	43955.	0.73982	1288.0	45.819	36488.	7623.0	4116.4	3401.5	514.51	133.38	45064.
	25.17	3249.4	5509.2	4.9700	7623.0	24.000	4352.5	40.77	41940.	760.	1559.
	0.32903	98.5	3914.4	11229.	7850.0	500.75	427.20	43441.	2142.	3795.6	32519.
33.000	45752.	0.73371	1340.5	45.200	37658.	7727.6	4172.9	3451.8	516.18	140.51	46942.
	33.95	3297.6	5654.6	5.0600	7727.6	24.000	4472.8	39.50	43285.	1069.	2175.
	0.33459	136.0	4006.3	11420.	7983.4	490.59	431.20	45236.	3004.	3967.6	33569.
34.000	47628.	0.72742	1394.7	43.574	38884.	7839.6	4233.4	3505.9	506.07	148.09	48913.
	45.74	3348.0	5799.1	5.1500	7839.6	24.000	4594.6	38.27	44694.	1504.	3039.
	0.34009	187.6	4100.9	11614.	8119.1	503.20	435.20	47122.	4211.	4147.4	34646.

TIME	GSP	PGSP	BPOP	AGSP	PDISI	PD14	TOLF	BLAF	AGPR	BCSK	BPS
	GGSP	PPOP	HPOP	WAGE	PD140	BR	GWAG	ALAF	PINCM	GDER	BDS
	BGSP	GPOP	GNPO	POP	PD14A	AGDT	GLAF	BPPN	GPUR	STK	PCONS
35.000	49634.	0.72074	1453.3	43.888	40236.	7972.8	4305.3	3570.7	518.38	156.14	51009.
	61.53	3406.5	5942.5	5.2400	7972.8	24.000	4717.9	37.08	46248.	2114.	4247.
	0.34583	258.6	4202.2	11812.	8257.1	499.96	439.20	49115.	5902.	4349.7	35773.
36.000	51766.	0.71508	1519.4	42.916	41622.	8108.3	4378.5	3636.7	515.52	164.72	53278.
	82.67	3465.0	6085.4	5.3300	8108.3	24.000	4842.6	35.92	47842.	2969.	5939.
	0.35259	356.3	4309.4	12012.	8397.5	503.98	443.20	51250.	8268.	4590.3	37017.
37.000	54017.	0.70890	1589.8	42.520	43044.	8246.1	4452.9	3703.7	519.44	173.91	55632.
	110.99	3523.5	6228.8	5.4200	8246.1	24.000	4968.8	34.79	49476.	4167.	8306.
	0.35956	490.8	4421.6	12216.	8540.2	505.30	447.20	53497.	11580.	4809.9	38292.
38.000	56396.	0.70219	1664.6	41.925	44503.	8386.3	4528.6	3772.0	520.89	183.77	58134.
	148.90	3582.0	6372.6	5.5100	8386.3	24.000	5096.5	33.70	51153.	5845.	11620.
	0.36671	675.9	4539.2	12424.	8685.4	501.88	451.20	55875.	16217.	5052.5	39601.
39.000	58909.	0.69501	1740.5	40.957	45999.	8528.8	4605.6	3841.4	517.50	194.34	60783.
	199.64	3640.5	6516.9	5.8000	8528.8	24.000	5225.7	32.63	52872.	8196.	16258.
	0.37332	930.8	4662.3	12635.	8833.0	506.03	455.20	58392.	22709.	5310.5	40943.
40.000	61578.	0.68724	1822.4	40.588	47532.	8673.8	4683.8	3912.0	521.56	205.64	63588.
	267.44	3699.0	6661.7	5.6900	8673.8	24.000	5356.3	31.59	54635.	11489.	22751.
	0.38031	1281.6	4792.0	12850.	8983.1	496.66	459.20	61056.	31796.	5584.1	42319.

APPENDIX C

GLOSSARY OF ABBREVIATIONS

GLOSSARY OF ABBREVIATIONS

The symbols within parenthesis of the glossary represent the units as indicated below:

(d)	Dimensionless
(dh)	Dollars per hour
(dhy)	Dollars per hour per year
(dy)	Dollars per year
(tp)	Thousands of people
(tpy)	Thousands of people per year
(md)	Millions of dollars
(mdy)	Millions of dollars per year

Abbreviations

AGAOT	Average agriculture output (mdy)
AGILF	Agriculture increase in labor force (tp)
AGI	Actual values of AGOT between T=0 to 10 years (md)
AGN	Computed value of AGOT beyond 10 years (md)
AGOT	Agriculture output (md)
AGPR	Agriculture production (md)
ALAF	Agriculture Labor force (tp)
ALC	Actual values of AGILF between T=0 to years (tpy)
ALM	Exponential value of variable S (d)

ALN	Computed value of AGILF beyond 10 years (tpy)
ALR	Constant to determine ALD (d)
APC	Average propensity to consume (d)
BASL	Business actual sales (mdy)
BCAP	Business capacity (mdy)
BCSK	Business capital stock
BDPR	Business depreciation
BDS	Business desired sales (mdy)
BEPN	Business expected production (mdy)
BFL	Business labor force beyond 10 years (tp)
BGINV	Business gross investment (mdy)
BGSP	Business gross investment per GSP (d)
BLAF	Business labor force (tp)
BLE	Actual values of business labor force between T=0 to 10 years (tp)
BLINC	Actual values of increase in BLAF (tpy)
BPOP	Per capita gross business investment (dy)
BPPN	Business possible production (mdy)
BPR	Business production (mdy)
BPS	Business possible sales (mdy)
BRER	Business retained earning
BSAV	Business savings
BTAB	Table value of BLINC between T=0 to 10 years (d)

BL4	Boxcar functions with four boxcars
BX1	Boxcar function representing population for age 0 to 13 years
BXSM	Sum of people for 0 to 13 years for age 0 to 13 years (tp)
CAPF	Capital factor obtained from BCSK (d)
CIN	Fraction of PDISI invested in housing (d)
DEB	Delay in debts accumulation (year)
DT	Delta time (year)
FBR	Final birth rate (d)
FCAPF	Intermediate variable obtained from CAPF (d)
FLABF	Intermediate variable obtained from LABF (d)
GBBE	Government buffer expenditure (mdy)
GDEB	Government debts (md)
GEXP	Government expenditures (mdy)
GGSP	Government expenditures per GSP (dy)
GINP	Government interest payment (mdy)
GINV	Government investment (mdy)
GKN	Fraction based on GINV and GPUR (d)
GL	Value of GLIN after T=0 years (tpy)
GLAF	Government labor force (tp)
GLIN	Annual Growth rate of GLAF (tpy)
GNPO	Per capita gross state product (dy)
GPOP	Per capita government expenditures (dy)
GPUR	Government purchases (mdy)

GSER	Government public expenditures (md)
GSIN	Annual increment in GSER (mdy)
GSP	Gross state product (md)
GT	Value of GLIN between T=0 to years (tpy)
GTAX	Government taxes (mdy)
GWAG	Government payroll (mdy)
GW1	Half the percentage growth of GSP (d)
HC	Fraction of housing stock depreciated (d)
HDEP	Housing depreciation rate (mdy)
HPOP	Per capita housing stock (dy)
IMDG	Implicit deflator in GSP (d)
INCRW	Increment in wage rate(dhy)
IND	Value of IMDG after T=10 years (d)
INF	Value of IMDG at T=10 (d)
ING	Value of IMDG between T=0 to 10 years (d)
INIF	Average increase in inflation (d)
INT	Interest rate (d)
INTVB	Intermediate variable depending on BEPN (d)
INWA	Initial wage rate (dh)
NMIG	Net migration rate (tpy)
NMR	Net migration rate beyond 10 years (tpy)
NNT	Net migrate rate between T=0 to 10 years (tpy)
PA	Intermediate variable to determine PFA (d)

PARRT	Participation rate of labor force (d)
PCONS	Personal consumption (mdy)
PDB	Value of PDISI between T=0 to 10 years (mdy)
PDR	Value of PDISI after T=10 years (mdy)
PDISI	Personal disposable income (mdy)
PFA	Intermediate variable determining PDFA (d)
PGSP	Personal consumption per GSP (d)
PHST	Personal housing stock level (md)
PINCM	Personal income (mdy)
PINH	Personal investment in housing (mdy)
PINR	Population growth rate
PM	Utilization coefficient of BPPN (d)
PN	Intermediate variable band on per capita GSER (mdy)
PO14	Actual population 14 years and older (tp)
PO14A	Population 14 years and older based on POPF (tp)
PO14O	Population 14 years and older based on BXSM (tp)
POFA	Projected value of population fraction 14 year and older (d)
POFT	Actual population fraction 14 years and older (d)
POP	Total population (tp)
POPF	Likely population fraction 14 years and older (d)
POPFA	Actual population fraction 14 years and older (d)
POPFS	Computed population fraction 14 years and older (d)
POPT	Decrease in the value of POPFS (d)

PPGIN	Population increment rate (tpy)
PPGR	Net population in a given year (tp)
PPOP	Per capita personal disposable income (dy)
PS	Intermediate variable depending on GPUR (mdy)
PSAC	Personal savings account (md)
PSAV	Personal savings (mdy)
S	Variable depending on time T (d)
STK	Stock level of the output (mdy)
T	Time reckoned from the year 1952 (y)
TAXF	Tax factor (d)
TOLF	Total labor force (tp)
UNM	Unemployment level of Michigan (per cent)
UNMDF	Unemployment differential (d)
UNN	Unemployment level of Nation (per cent)
WAGE	Wage rate (dh)

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